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NOTES AND COMMENTS.

Annealing Malleable Iron Castings.

In our last issue we published in abstract a Paper recently presented by Mr. W. P. Putnam before the Detroit Foundrymen's Association, in which the author dealt with the effects of temperature and length of heating on malleable castings. A number of castings, it will be remembered, of the same composition, were sent to different foundries to anneal, and the results showed considerable variations, resulting from variations in the annealing temperature and the time of annealing. The actual effect of annealing has been the matter of considerable controversy in the past, some claiming that the malleable properties of the finished casting resulted from the extraction of a certain percentage of the carbon, and others that it was caused solely by a change in the nature of the carbon. Undoubtedly, in the Reaumur process (the usual English practice) employing irons comparatively high in sulphur, the elimination of the carbon is more pronounced than in the case of American practice, where low-sulphur irons are used, and the product is known as "black-heart" malleable cast iron. But the great essential is the reduction of the carbides in the casting to free iron and free carbon, the latter existing in a more finely-divided state than is the case with ordinary grey-iron castings. In the case of the samples above mentioned it may be taken that they were of the "black-heart" variety, in the production of which the practice is to anneal in mill scale or slag. In this process the effect of the annealing is not so much to eliminate the carbon as to precipitate the combined carbon as finely-divided amorphous graphitic carbon. The results quoted, however, indicate a more or less considerable loss of carbon, for the analysis of the unannealed bars showed C.C. 2.70 per cent., while the finished castings contained total carbon (practically all in the graphitic state) in no case up to 2.0 per cent. But as regards the conclusions drawn by the author, it is difficult to see how these were arrived at. He states first that "in each case under too high temperature or a long period of annealing, the carbon was nearly all removed. Either practice is wasteful and produces poor malleables for some purposes." The highest temperature given in the table was 2,200 deg. F., and the casting showed G.C. 0.40 and C.C. trace; but it had a tensile strength of 50,849 tons, or the highest of the specimens quoted, and elastic limit 41,792 tons, which was again the highest figure quoted. The author claims that to heat the castings much above the proper annealing temperature for a long period is unnecessary, is wasteful of fuel, and produces poor castings for some purposes, and he shows in the diagram of proper finishing temperatures about 1,570 deg. F. as the correct finishing temperature for castings with 2.70 per cent. carbon. But among the samples for which full particulars are quoted, the one which gave the best results was annealed at 2,200 deg. F. for 96 hours, and lost 2.30 per cent. carbon, while another specimen annealed at 1,650 deg. F. for 208 hours lost 1.90 per cent. carbon, and gave the next

best tensile test result. The sample which was annealed at 1,620 deg. F. (or within 50 deg. of the "proper finishing temperature") for 101 hours gave the poorest test results. It would appear, then, that a high temperature for a comparatively short period is better than a low temperature for only a slightly longer period, for while in the case of the low-temperature sample quoted the carbon was all in the graphitic state, annealing had, apparently, not been carried to the full extent. But in order to strictly compare the results obtained, it is first necessary to know what the annealing temperatures quoted actually represent. Were they the ultimate heats attained in the ovens, the finishing temperatures of the actual castings, or the average heat of the castings throughout the annealing process? Presumably, the heat of the oven is given, but this must not be taken as the heat of the castings; for, as shown by the second diagram in Mr. Putman's article, the temperature of the casting remains from 50 to 150 deg. below the oven heat. During the process, the fluctuations of furnace temperature either way are only partially reflected in the temperature of the castings, and an oven temperature of 1,620 would probably mean that the sample was most of the time below 1,570 deg. F. Since the carbon forms into graphite at 1,475 deg. F., that change would take place, but the necessary heat to complete the process would probably not be attained for any considerable time. Where the same temperature was employed, but the casting was annealed for 208 hours, the tensile test results were high, accompanied by a material reduction in the carbon content. So far, then, as it is safe to base conclusions on these few tests, it may be deduced that while fuel wastage may result from high temperatures, unless full time is allowed for the process at a lower temperature, it is better to maintain the heat of the oven above the nominally correct point. The reduction in the carbon content, too, seems to be closely associated with increased strength, but the condition of the graphite is, of course, the primary question.

Vanadium in Cast Iron.

A feature of last month's meeting of the Iron and Steel Institute was the number of papers dealing with the effects of special constituents in iron and steel, and not the least interesting was Mr. W. H. Hatfield's contribution, on "The Influence of Vanadium upon the Physical Properties of Cast Irons," which is dealt with on page 316 of this issue. There are many foundrymen who regard the addition of special elements to cast iron, for the purpose of cleansing the metal and increasing its strength, etc., as so much "physicking," and accordingly class it as unnecessary where mixing and melting are properly carried out; but, nevertheless, more than academic interest surrounds any means whereby the properties of cast iron may be raised above the normal. Vanadium, of course, is no new addition to the founders' "medicine chest;" for some years now it has been more or less extensively used in America for both iron and steel, and lately it has also enjoyed increased use in this country. From the results which have at times been quoted for vanadium irons, it would appear to give at least considerably increased resistance to abrasion. Opinion is divided as to whether it acts as a scavenger, cleaning out the oxygen and nitrogen from the metal, but that it imparts additional strength is now beyond dispute. The really important point, however, was that raised by Mr. J. E. Stead, who questioned whether other substances such as manganese, could not be made to give the same results, while being at the same time much cheaper. Without any doubt, there is yet a wide field unexplored in the art of alloying iron, and while experimenters have revealed many possibilities regarding the use of special constituents, it would be presumptious to suppose that there are not wider fields practically untouched. There is, certainly, a good deal to be said for the contentions of those who consider that given good iron (for example, cold-blast pig) good results may be obtained by a judicious mixture without the use of vanadium and similar elements. At the same time it need not be impressed upon any foundryman that to employ first-class iron of this nature may prove more expensive than adding special constituents. The promiscuous use of the "medicine chest" is not to be recommended under any circumstances, for not only are doctors' bills a heavy item as compared with healthy exercise in the shape of intelligent and proper mixing and melting (and there are some who are inclined to introduce a scavenger into the metal to do the work of the furnace man), but at times most unexpected and undesirable results are obtained, which fact again exemplifies the "importance of the next-to-nothing"—a phrase employed by one of our greatest scientists, and signifying the effect of minute quantities of certain elements. The constitution of cast iron is to complex to allow indiscriminate meddling, but this same complex character allows the production of ferrous alloys that were impossible until the influence of the special constituent was made the subject of research and experiment.

The Growth of Cast Iron After Repeated Heatings.

A further tribute to the possibilities before the use of special constituents in cast irons was involved in the Paper on "The Growth of Cast Iron after Repeated Heatings," presented before the same meeting of the Iron and Steel Institute by Dr. H. C. H. Carpenter. This Paper was the conclusion of the one by Professors Carpenter and Rugan which we dealt with in our issue of November, 1909. The conclusions arrived at as the result of the investigations recorded therein are worthy of review. As regards the effects of the different constituents of cast iron, silicon was dealt with in the previous Paper. Phosphorus tends to diminish growth, 0.3 per cent. lessening the growth by about 3 per cent. The effect of sulphur also, is in the direction of retardation, while manganese retards the rate of growth in all cases, and diminishes the absolute amount in the majority of cases. Dissolved gases have no influence on the growth of an iron containing more than 3 per cent. of silicon, but between 1.75 and 3.0 per cent. of this element they may cause a growth of from 1 to 2 per cent. The influence is most potent when silicon does not exceed 1 per cent., and in such cases they may be responsible for a growth of at least 10 per cent. Alloys containing from 2.25 to 2.40 per cent. of carbon, and 0.40 to 0.48 per cent. of silicon, showed a reduction of growth from 7.49 to 3.09 per cent. on increasing the manganese from 0.510 to 0.935 per cent. An alloy containing 2.66 per cent. of carbon, 0.587 per cent. of silicon, and 1.64 per cent. of manganese, showed no signs of growth after 150 heats, but, on the contrary, a slight contraction, namely, about 0.13 per cent. A perusal of Dr. Carpenter's report shows that the key to the question lies in the use of manganese, and it may here be stated that for the practical man the most important point in the research is the determination of an alloy which will not grow after repeated heatings. The uses for such an alloy are too well known to require detailed enumeration here, but according to Dr. Carpenter it appears to be a suitable material for annealing ovens, rolls, fire-bars, and the grids of muffle furnaces, whose growth when in the form of grey irons is so objectionable a feature. While from the point of view of minimum growth and non-cracking the most suitable material for ingot

moulds into which molten steel is cast appears to be a very mild steel, the application in the iron foundry of the alloy under consideration is sufficiently important to make Dr. Carpenter's researches of considerable practical value, apart from the scientific interest attached thereto.

Electric Smelting of Iron and Steel.

At the annual meeting of the Association of Mining Engineers in Sweden, Mr. Axel Lindblod read a Paper on the experience gained during the last few years, from which the following details are extracted. He pointed out that in 1903, when the Canadian Commission undertook their investigations, the total number of electric steel furnaces in work amounted only to three, viz., two in Sweden of the Kjellin and Héroult systems and one in Switzerland. Up to 1907, when the Germans acquired several patents, progress was very slow, but since that time the industry had developed at a wonderful pace, as is shown in the following table:—

	Number of Furnaces.	Total Capacity.	Amount of Energy.
1907	10	18.8 tons.	2750 Kw.
1908	26	96.2 ,,	12,625 ,,
Beginning of 1910 ...	57	215.4 ,,	26,575 ,,
,, ,, 1911 about	95	about 400 ,,	about 50,000 ,,

In Germany, the electric steel production comprised chiefly high-quality steel, while the Americans had tried electricity for the better classes of merchant steel. The production of high-grade steel in Germany especially threatened the export of steel from Sweden. As an instance of this it might be mentioned that the Stahlwerk Beeker, at Krefeld, which formerly used Swedish raw material, had now signed a five years' contract with the Electric Steel Works at Dommeldingen for the purchase of all raw materials for their production of crucible steel. The pig-iron used there had the following analysis: C=3.5 per cent., Si=0.6 per cent., Mn=1.2 per cent., S=0.12 per cent., P=1.8 per cent. The finished product, which was replacing Swedish material, had the following composition: C = 0.07—0.10, Si = 0.15, Mn=0.20—0.35, S=0.008—0.010, P 0.008—0.010. The Germans had besides quite lately made castings by the electrical method as a speciality. This comprised chiefly small castings, such as parts for motors, motor-cars, etc. The Stavanger Electrical Steel Works in Norway, which were under erection, would chiefly take up this branch of manufacture.

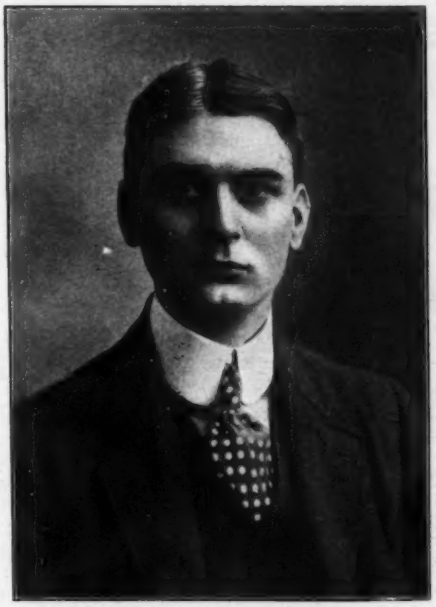
In Sweden, a two-ton Kjellin electric furnace had recently been erected at the Trollhattan Waterfalls, and in November, 1910, a new furnace was completed at Soderfers Bruk. At Kortfors, the plant had been extended, and 1,000 electrical horse-power was now used for electric steel production.

German Foundrymen's Association,

The annual meeting of the Verein Deutscher Giessereifachleute (German Foundrymen's Association) was held last month from the 25th to the 28th. The programme included a number of interesting items, amongst which was a visit to the foundry of the German Niles-Tool Works, at Oberschöneweide. The papers read at the meeting included "A New Moulding Process for making Hollow Castings," by Professor Dr.-Ing. A. Nachtweh (Royal Technical Institute, Hannover), the lecture being illustrated by cinematograph pictures; "The Present State of Metallography, with Special Reference to Foundry Practice," by Dr. F. Bennigson (Berlin), illustrated by cinematographic pictures; "The Rotary Fore-Hearth," by Th. Löhe (Hannover); and "The Use of Oil as a Heating Material in Foundry Shops," by Oberingenieur Karl Schiel (Berlin).

Carnegie Research Scholarship for B.F.A. Official.

At the meeting of the Iron and Steel Institute last month it was announced that amongst the Carnegie Research Scholarships awarded for the year 1911 was £100 to Mr. George Hailstone, of Birmingham, to enable him to carry out an investigation on liquid contraction in cast-iron. Mr. Hailstone was born in 1883, and was educated at Tindal Street Board School and the Municipal Technical School, Birmingham. From 1899 to 1902 he acted as assistant in the Metallurgical Department of the Birmingham Municipal Technical School, and from 1902 to 1905 was Demonstrator in Metallurgy. He obtained first-class honours in iron and steel manufacture, and honours in both theoretical and practical metallurgy. In 1905 he was appointed Chemist and Metallurgist to Messrs. W. and T. Avery, Limited, Soho Foundry, Birmingham.



MR. GEORGE HAILSTONE.

Mr. Hailstone is a member of the Council of the Staffordshire Iron and Steel Institute, an original member of the Birmingham Metallurgical Society, and a member of the British Foundrymen's Association, also being Hon. Secretary of the Birmingham Branch of that institution. He is the author of numerous papers on cast-iron, which have been read before the above Societies, and also the Coventry Engineering Society, at Birmingham, Coventry, Dudley, Glasgow, Manchester, and Cardiff. The following is a list of his published papers: "The Characteristics of Foundry Irons"; "The Action of the Metalloids on, and the Microstructure of Foundry Irons"; "The Sampling of Pig-iron"; "The Scientific Mixing of Iron for Castings"; "The Work of an Iron Foundry Laboratory"; "The Microscopic Analysis of Cast-iron"; and "The Use of the Microscope in Foundry Practice." He is also joint author with Mr. F. J. Cook of a research on "The Effect of Structure on the Physical Properties of Cast-iron."

The Influence of Vanadium upon the Physical Properties of Cast Irons.*

By W. H. Hatfield, B.Met.

Of late years the metallurgy of cast iron has received considerably more attention than previously, and much research has been directed towards making such material more consistent in its behaviour under physical tests, both in the "as cast" and "annealed" condition. One phase of the development is the introduction of some of the elements such as have been employed in steel-making with advantage; vanadium is now suggested as a valuable influence in increasing the strength of cast iron, and as there is at present considerable disagreement as to exactly what the influence of this element is, it was thought that the results of the following experiments conducted in our works' laboratories might be of interest.

There are existing, at present, the results of several sets of experiments published by various workers, which are more or less conclusive in showing the advantage of the addition of the element in small quantities.

G. L. Norris† gives an instance where vanadium increased the life of locomotive cylinders. Cylinders made of cast iron not treated with vanadium showed a wear of $\frac{1}{32}$ in. per 100,000 miles, whereas vanadium cast-iron cylinders showed only microscopical wear after running 200,000 miles. Average tests upon such irons gave the following result:—

	Transverse strength.	Tensile strength.
	lbs.	lbs.
Plain cast iron	2,130	24,225
Vanadium cast iron	2,318	28,728

The New York Central Railroad Company have already ordered a considerable number of engines equipped with vanadium cast-iron cylinders.

J. Kent Smith gives interesting figures in an article in the American "Foundry" of February, 1909. He considers that the action of vanadium is threefold:—(*a*) That it acts as a scavenger, clearing out the oxygen and nitrogen, which he considers exist under certain conditions in cast iron. (*b*) That it "somewhat strengthens the iron by its solid solution in the carbonless constituent of that iron, rendering the molecules of its constituents more coherent than ever, and their crystals more resistant to abrasive wear and less susceptible to breakage by disintegration along the cleavage lines." (*c*) By its action upon the carbides.

The author does not agree with Kent Smith upon the first action, since he does not consider that oxygen is present in properly melted iron of suitable composition, but considers that his second and third claims deserve consideration. Kent Smith proceeds to substantiate his observations with experimental results, and shows that he has increased the tensile strength of cylinder and other cast irons 50 per cent. by the addition of 0.2 to 0.25 per cent. of the element. He also gives instances of similarly increased figures under the transverse tests, and further demonstrates that these results are not at the expense of the deflection by recording figures obtained from the standard American bars as high as 0.145. Under compression and hardness tests he also records improvement. It is also claimed that parts subject to much wear are improved by the addition of small quantities of the element, and in this matter support is obtained from a theoretical reasoning of the matter.

Dr. R. Moldenke‡ describes some interesting experiments made to determine the influence of this element upon the properties of cast iron. The iron was melted in the cupola, and the additions of manganese and vanadium were made to the metal when in the ladle. The test-bars were cast to the standard size of the American Society for Testing Materials, *i.e.*, 1¼ in. in diameter cast on end, in dried moulds. The testing was done upon a 5,000-lb. Richle testing machine, and some of the results are given in Table I.

TABLE I.

Dr. Moldenke's Experiments.

Iron melted.	Analysis. Va.	Mn.	S.	P.	Si.	Broke at lbs.	Deflection in inches.	Modulus of Rupture.
	%	%	%	%	%			
Machinery iron	—	0.54	0.065	0.66	2.72	1,980	0.105	38,680
,,	0.27	0.56	,,	,,	,,	2,360	0.100	46,070
,,	0.33	0.54	,,	,,	,,	1,980	0.100	38,700
,,	0.36	0.59	,,	,,	,,	2,372	0.09	46,320
Remelted white iron car wheels	—	0.4	0.13	0.38	0.58	1,470	0.05	28,100
,,	0.22	0.54	0.08	0.37	0.50	3,920	0.095	76,650
,,	0.25	1.15	0.11	0.59	0.65	2,970	0.09	58,040
,,	0.27	0.74	0.08	0.43	0.53	3,030	0.09	59,220
,,	0.31	0.45	0.119	0.41	0.45	2,800	0.055	54,890
,,	0.36	0.40	0.09	0.42	0.45	3 020	0.060	59,030
,,	0.45	0.40	0.11	0.41	0.42	2,950	0.070	59,230
Burnt grey iron	—	0.35	0.09	0.63	2.13	1,310	0.090	25,500
,,	0.05	0.35	0.09	0.63	2.13	2,220	0.100	43,380
Burnt white iron	—	0.43	0.14	0.42	0.41	1,440	0.050	28,170
,,	0.05	0.65	,,	,,	,,	1,910	0.055	37,400

The author, however, wishes to point out one or two considerations which must not be overlooked when deductions are being drawn from the foregoing experiments. Better results were undoubtedly obtained with the vanadium content than without it; it is, however, difficult to obtain any distinct rule, since the influence of 0.22 per cent. of the element would seem to be as great as that of 0.45 per cent. In the case of burnt metal, either white or grey, a distinct advantage would appear to be obtained by the addition of so low a percentage as 0.05. It is, however, important that we should take into consideration the variable analyses, and it is to be noted that the condition of the carbon is not recorded.

It will appear from the foregoing data that vanadium strengthens cast iron, and the present author has, himself, under certain conditions, found such to be the case. His observations, however, pointed to the view that this action was merely due to the influence of that element upon the condition of the carbon, i.e., it assisted the carbon to persist in the combined state. Now by scientific working, as is fully appreciated, the condition of the carbon can be completely controlled without access to any special ele-

* Read before the Iron and Steel Institute, May, 1911.

† "New England Foundrymen's Association," May, 1910.

‡ "American Foundrymen's Association," 1907.

FIG. 1.—AS CAST.

FIG. 2.—QUENCHED 860° C.

FIG. 3.—QUENCHED 960° C.

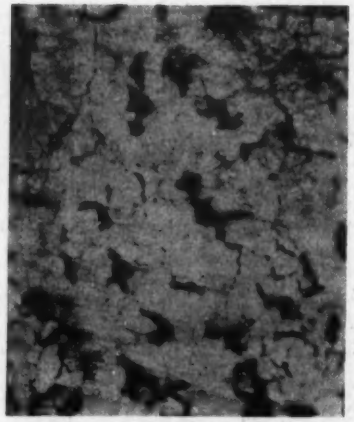


FIG. 4.—QUENCHED 1040° C.

V.—WHITE CAST IRON (NO VANADIUM). MAGNIFIED 52 DIAMETERS. ETCHED HNO_3.

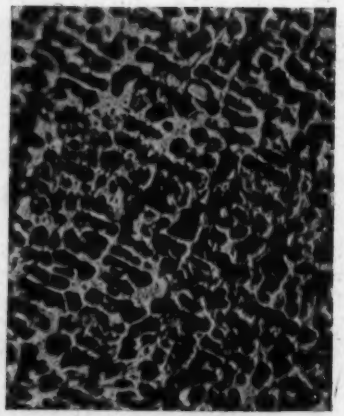


FIG. 5.—AS CAST.

FIG. 6.—QUENCHED 860° C.

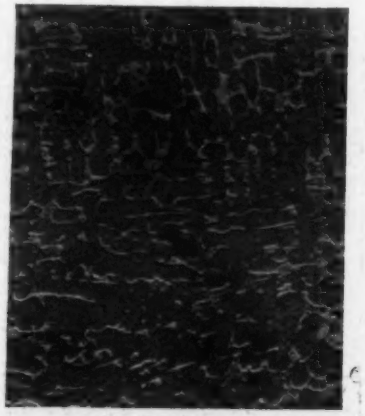


FIG. 7.—QUENCHED 960° C.

FIG. 8.—QUENCHED 1040° C.

VI.—WHITE CAST IRON (0.138 PER CENT. VANADIUM). MAGNIFIED 52 DIAMETERS. ETCHED HNO_3.

ments, and it was therefore decided to determine whether any additional advantage over the ordinary procedure was to be gained by the addition of the expensive alloy of vanadium. To sum up, the question to be decided was whether or not the carbides in the treated iron were in any way different from those in the untreated iron.

Author's Experiments.

The iron used for these experiments was one in which normally the whole of the carbon was in the combined state. To the molten metal varying quantities of 45 per cent. ferro-vanadium were added, and the analyses of the resulting materials are given in Table II.

TABLE II.

Number.	Combined Carbon.	Graphite.	Silicon.	Mn.	S.	P.	Va.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
V	2.91	nil.	0.66	0.28	0.03	0.08	—
V1	2.92	„	0.66	0.28	0.03	0.08	0.138
V2	2.9	„	0.653	0.28	0.03	0.08	0.22
V3	2.9	„	0.65	0.28	0.03	0.082	0.45
V4	2.9	„	0.65	0.28	0.03	0.084	0.65

It will be seen that a most interesting set of alloys were thus prepared of like composition apart from the gradual increasing vanadium content. The whole of these irons presented the normal fracture of white cast iron and microscopically (Figs. 1, 5, 9, 13, and 17), were found to present the usual cementite pearlite structure of white iron.

It was considered that the hardness test would be the most likely one to determine whether the vanadium had any influence over the physical properties, and the bars were therefore subjected to both the Brinell and scleroscope tests. The results obtained are given in Table III.

TABLE III.

Number.	Brinell.	Sclerescope.
V	387	48
V 1	418	49
V 2	430	48
V 3	418	47
V 4	430	48

It will be seen that there is no evidence in favour of any pronounced effect peculiar to the vanadium, and it was therefore considered that any influence which the element possibly had was simply the indirect one.

Conclusively to prove the manner in which the influence of the element was exerted, it was considered necessary to find out how it existed in the alloy. If vanadium is added to pure iron it alloys in all proportions, and an interesting research has resulted in the production of an equilibrium diagram.* If added to a steel of carbon content under saturation, it will be found that the vanadium above the pearlite change point exists in solid solution. After the resolution of the hardenite into pearlite, although it would seem so to be believed, it is not as yet proved that the vanadium exists as a constituent of the pearlite carbide as distinct from the pearlite ferrite.

The alloys which we have under consideration belong to the supersaturated range, and it was therefore decided to determine what proportion of vanadium crystallised with the massive cementite as distinct from the solid solution. So that the massive cementite should be alone separated, the samples were quenched just above the recalescence, previous to the electrolytic separation. In this manner the solid solution was taken into solution in the dilute hydrochloric acid whilst the cementite carbide remained behind. The author appreciated that it was possible for the vanadium compound in the solid solution to remain undissolved, but experience showed that this was not so, as some vanadium was found in the HCl solutions. The samples were exposed for forty-eight hours in each case, and Table IV. gives the analysis of the cementite carbides thus produced.

TABLE IV.

Bar.	Carbon.	Vanadium.	Silicon.
	Per cent.	Per cent.	Per cent.
V	6.59	—	0.58
V 1	6.54	0.414	0.26
V 2	6.54	0.66	0.32
V 3	6.53	0.81	0.31
V 4	6.54	1.25	0.31

It will be seen that the bulk of the vanadium crystallised with the cementite carbide, and it would be deduced that it was probably in chemical combination. The author has shown* that with the varying silicon content of an iron the silicon content of the carbide of such an iron is modified, and further that this silicon content is responsible for the comparative stability of such carbide at high temperatures. It is thus interesting to find that not only does the vanadium crystallise with the carbide, but that it influences the percentage of silicon found in it. Here is possibly a further manner in which the influence may be asserted. The carbon content of these alloys was approximately 2.90 per cent., and if the calculation be made it will be found that about 34.5 per cent. of the alloy is really carbide. In connection with this fact the following table is of interest as showing the yield of carbide obtained:—

Number.	Carbide obtained.	Alloy in solution.	Carbide obtained.
	Grammes.	Grammes.	Per cent.
V	2.319	5.339	30.2
V 1	2.51	5.71	30.5
V 2	2.54	5.008	31.17
V 3	4.11	8.166	33.4
V 4	3.12	6.18	33.54

The silicon not found in the carbide was invariably found in perfect solution in the HCl, and as an instance of this the silicon in the solution of V3 worked out at 0.95 per cent. for the solid solution, thus clearly demonstrating that the silicon had been partially prevented from crystallising with the carbide by the vanadium content. Such experiments as these are somewhat crude, but they, at any rate, give results which throw light upon the grouping of the elements in such materials.

Heat Treatment Experiments.

It was next decided to determine by heat-treatment exactly how far the stability of the carbide was influenced by the modified composition brought about by these additions. Bars of each number were heated in a Clinch-Jones muffle for about one hour at fixed temperatures, and then quenched. In each instance the bars were introduced into the muffle already standing at the particular temperature, which was subsequently maintained within plus or minus 5 degrees C. for the stated period.

Figs. 1, 5, 9, 13, 17 clearly show that previous to treatment the whole of the series were practically

* Vogel and Tammann, "Zeitschrift für Anorganische Chemie," vol lviii., pp. 73-82.

* Royal Society, Nov. 10, 1910.

FIG 9.—AS CAST.

FIG. 10.—QUENCHED 860° C.

FIG. 11.—QUENCHED 960° C.

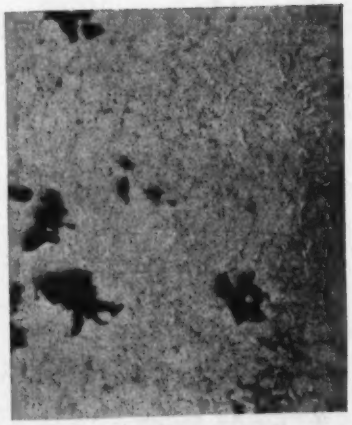


FIG. 12.—QUENCHED 1040° C.

V2.—WHITE CAST IRON (0.22 PER CENT. VANADIUM). MAGNIFIED 52 DIAMETERS. ETCHED HNO_3.

FIG. 13.—AS CAST.

FIG. 14.—QUENCHED 860° C.

FIG 15.—QUENCHED 960° C.

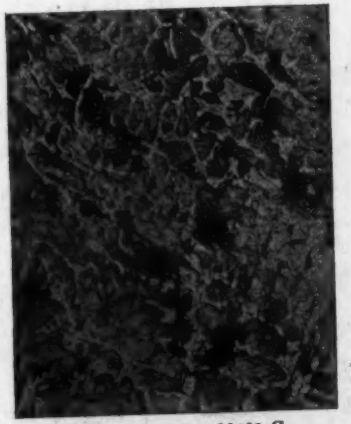


FIG. 16.—QUENCHED 1040° C.

V3.—WHITE CAST IRON (0.45 PER CENT. VANADIUM). MAGNIFIED 52 DIAMETERS. ETCHED HNO_3.

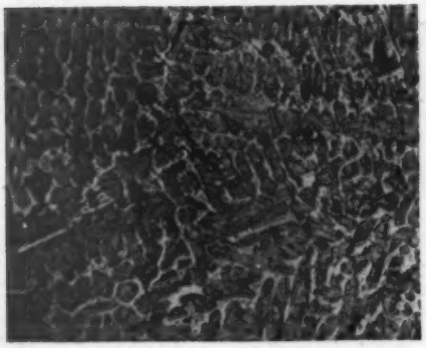


FIG. 20.—QUENCHED 1040° C.

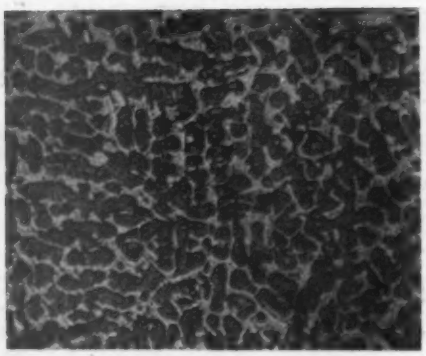


FIG. 19.—QUENCHED 960° C.

FIG. 18.—QUENCHED 860° C.

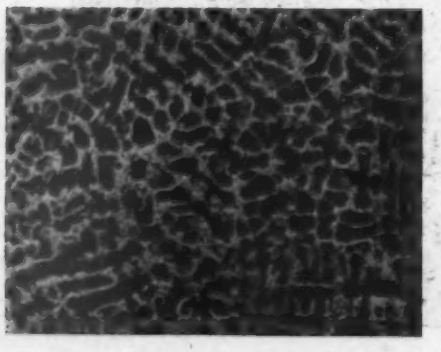


FIG. 17.—AS CAST.

V4.—WHITE CAST IRON (0.65 PER CENT. VANADIUM). MAGNIFIED 62 DIAMETERS. ETCHED HNO_3.

identical in structure; they consisted of cementite and pearlite.

The first experiment was the heating at 860 degrees C. for one hour, followed by the rapid quenching. Microsections prepared and etched with dilute nitric acid revealed the structures shown in Figs. 2, 6, 10, 14, and 18. Apart from a slight precipitation in the bar V, there is very little difference in the structures presented.

The second series were heated for one hour at 960 degrees C. and rapidly quenched. The respective structures are shown in Figs. 3, 7, 11, 15, and 19. In bar V (Fig. 3) the free carbide is nearly all broken down, only isolated areas being in evidence. In bar V1 (Fig. 7), little change seems to have taken place apart from the gradual disappearance of the free carbide, owing to solvent action of the solid solution with increasing temperature; occasional nodules of annealing carbon are noticed. The same remark applies to V 2 (Fig. 11). The structure of V 3 (Fig. 15) showed, however, no trace of the dissociation of the carbide, the whole of the carbide not in solution being presented as cementite. V 4 (Fig. 19) naturally presented much the same appearance as V 3.

The final heat-treatment of an hour's exposure at 1,040 degrees C. followed as before by a rapid quenching from that temperature. The microstructures presented after this treatment are portrayed in Figs. 4, 8, 12, 16, and 20. It will be seen that in the case of V, containing no vanadium, the whole of the free carbide at this particular temperature has broken down with the appearance of considerable quantities of annealing carbon, whilst the matrix presents the typical martensitic structure characteristic of the solid solution when quenched under these conditions. The sample V1, containing only 0.13 per cent. of vanadium, still contains some free cementite carbide, along with a considerable proportion of free carbon. The sample V2 presents a similar structure, with still more free cementite carbide in evidence. The microstructure of V3 is interesting; it will be remembered that this bar contains 0.45 per cent. of vanadium, and this, no doubt, explains the persistence of the bulk of cementite carbide which is the most noticeable feature of the micrograph. There has, however, been a noticeable dissociation of the carbide with the production of some annealing carbon. The most interesting micrograph is that obtained from the sample V4. It will be seen that all the cementite-carbon not redissolved in the solid solution has persisted intact even after exposure to a temperature of 1,040 degrees C. for one hour.

Conclusions.

The deductions to be made from the results of the foregoing experiments are as follows:—

(1). Additions of vanadium have a definite influence upon the physical properties of cast iron.

(2). This influence is mainly that of assisting the carbon to persist in the combined state.

(3). The persisting carbides, physically, do not differ materially from the normal carbide found in the cast iron.

(4). Owing, however, to the actual presence of much of the vanadium in the carbide, that carbide is rendered more stable.

We have received from the Anglo-American Oil Company, Limited, 36.38, Queen Anne's Gate, Westminster, S.W., an interesting booklet on "Liquid Fuel," calling attention to the great field offered for the application of liquid fuel in various smelting, enamelling, and metallurgical processes, in addition to its value for steam-raising and marine purposes.

The Mechanism of the Production of Malleable Castings.*

By Donald M. Levy, M.Sc., Assoc.R.S.M.

Within recent years a considerable amount of investigation has been undertaken with a view to obtaining an insight into the changes in constitution and composition which occur in cast-iron during the production of malleable castings; to trace the mechanism by which such transformations are brought about, and to assist in ascertaining the connection between the constitution and properties of the metal during the process.

It is the object of the present Paper to review the present state of our knowledge of the mechanism involved in the production of malleable castings, from the point of view of the changes in constitution undergone by the metal, by which it is transformed from the hard and brittle raw material of the process to the soft and ductile finished product, and of the manner in which some of the different factors of composition, temperature, etc., met with in practice tend to influence this change, reviewing the general principles which are involved in the transformations.

Varying opinions are held with respect to the most suitable means of representing the constitution of cast-irons on a general scientific basis; what is known as the "carbide system" lends itself advantageously for the purpose. The carbide view suggests that for this study, cast-irons and carbon-steels may be conveniently regarded as being primarily a series of alloys of iron and iron-carbide and that the graphitic system may be looked upon as a secondary one, derived from the decomposition of the carbide alloys; so that, according to this view, in general, graphite probably does not separate as such from molten cast-iron, but results from the decomposition of primarily separating or separated carbide.

It may be mentioned that this view recognises the possibility of direct graphite separation from the molten metal under certain physico-chemical conditions, such as high concentrations and temperatures, as the known experience in physical chemistry admits of such primary decomposition and separation. Instances of the primary decomposition of strong carbide solutions at high temperatures are, however, exceptional.

In support of the carbide view, there may be urged the fact, well-known in physical chemistry, that there is a marked tendency for the separation of intermediate unstable phases during a change from one stable phase to another; so in the case of cast-irons, although the stable phases in the solid metal are represented by free carbon and free iron, it is the unstable carbide phase which usually tends to separate from the liquid metal on solidification and the free carbon results from the instantaneous or subsequent decomposition of this comparatively unstable material.

The technical details of the two processes in common use for the production of malleable castings, the English or ore-annealing process and the American or Black Heart method, are familiar. For the present purpose it may be recalled that owing to the oxidising effect of the hematite employed in the former process there is a decrease in the carbon contents of the metal; but the actual changes in the carbon condition are in each case governed by the same general principles. The Black Heart process involves only this change in carbide condition, and being, therefore, simpler to follow, has been traced out in detail more closely.

A white iron, such as would be suitable for "malleablising," might contain about 3.0 to 3.5 per cent. of carbon, almost all of it in the combined form, low proportions of silicon (a small quantity appears to be essential, but excess is objectionable), whilst fairly low manganese and freedom from phosphorus and sulphur are desirable. The metal being melted and cast into the required shape results in a casting which is perfectly white when fractured, crystalline, brittle and hard enough to scratch glass.

In such an iron practically the whole of the carbon exists in the combined form, in combination with iron as a chemical compound iron-carbide Fe_3C, hard, crystalline and brittle. The metal of 3.5 per cent. carbon thus contains $Fe_3C/C \times 3.5 = 180/12 \times 3.5$, or 52.5 per cent. of this iron carbide, and it will thus be understood why a material of which more than half is such a hard and brittle constituent should itself be distinguished by somewhat similar characteristics. The fact that any stated quantity of combined carbon existing as Fe_3C in an iron is present in Fe_3C/C or 180/12, or 15 times that proportion of hard and brittle carbide is well worthy of note; and that although up to proportions of about 0.9 per cent. carbon, this carbide is a constituent of pearlite and thus has its effects modified by association with interstratifying layers of iron, any further excess is present as the free compound, the effect of which on the metal may thus be readily accounted for.

The analogy between cast-irons of any particular combined carbon content and steels of similar carbon proportion, both as regards constitution and properties, is of considerable assistance, as is also the fact that metal containing about 0.9 per cent. combined carbon is constituted almost wholly of pearlite, whilst smaller amounts are represented by a corresponding proportion of pearlite.

Supposing now that it be possible to decompose the whole of the carbide of the above-mentioned white iron into its elements, free carbon and free iron; the effect of this change on the constitution and properties must be very marked, since instead of the 52.5 per cent. of hard and brittle carbide there is formed but 3.5 per cent of passive free carbon and no less than 96.5 per cent. of free iron, which is soft, ductile and easily workable.

Though in cast-irons of ordinary composition the proportion of free carbon is an index of softness, this is not because of any intrinsic softening influence it possesses, but because it usually indicates the absence of a correspondingly large quantity of hard carbide and the presence of a correspondingly large amount of free iron, which is the element whose presence ensures the softness and ductility of the metal. Every 0.1 per cent. of combined carbon which is transformed to free carbon represents not only the destruction of 1.5 per cent. of carbide, but the liberation in its place of 1.4 per cent. of soft and ductile free iron.

The constitutional diagram of the iron-carbon alloys may now be considered in order to trace the sequence

* Paper presented before the Birmingham Branch of the British Foundrymen's Association, May 27.

in which the constituents of the cast-iron separate and solidify, Fig. 1 giving a general representation of these separations. The important fact must, however, be always kept in mind that the carbide whilst it is separating, or even subsequently, has a very strong tendency to decompose into the stable free carbon and free iron. It will be observed that the carbide in a white iron separates at two different periods and under two different sets of conditions. One portion separates directly from the molten metal (primary carbide), the other from a condition of solid solution in the iron (secondary carbide).

The solidification sequence of a 3.5 per cent. carbon cast-iron is represented by the line ONMP of Figure 1. Solidification of the metal commences at a temperature corresponding to the point N, when iron begins to solidify in the form of dendrites. This iron is not pure but has the power of holding in solid solution up to 1.7—2.0 per cent. of carbon; and to this material the name of austenite is given. Austenite continues to separate throughout the temperature range NM, during which time the remaining still molten liquid becomes richer and richer in carbon, until at point M the eutectic composition and temperature are reached and the molten residue of composition 4.3 per cent. of carbon

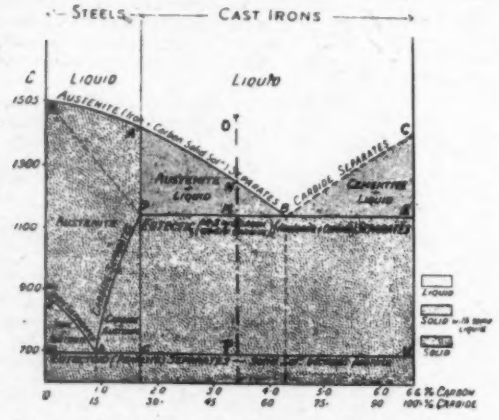


FIG. 1.—CONSTITUTIONAL DIAGRAM OF CAST IRONS AND STEELS.

becomes solid at 1,130 deg. C. This material is the eutectic of the iron: iron-carbide series; it has the characteristic appearance of eutectics, and is found surrounding the primary austenite crystals. It is composed of austenite and carbide, and this solidification corresponds with the separation of the first kind of carbide, which may be termed the *primary carbide*. The second separation of iron-carbide in the cast-iron takes place from the solid solution of iron-carbide in iron—the austenite. This separation from solid solution of the carbide is exactly analogous in general features to the separation of a material from aqueous solution. From 1,130 deg. C to 690 deg. C (range M.P., Fig. 1) more and more carbide gradually separates from the austenite, until at just above 690 deg. only about 0.9 per cent. of carbon remains in solid solution (a reduction of about one-half), and at this temperature this residual eutectoid solid solution suddenly becomes completely transformed into alternate layers of carbide and free iron, being the eutectoid known as "pearlite."

Microscopic examination of white irons shows that these final pearlite areas are surrounded by the borders of the secondarily separated carbide, so that the pearlite skeletons represent the position of the original austenite crystals.

It is by the decomposition of one or other or both of these carbides that the white cast-iron is converted into "malleable," more particularly in the black-heart process; and it is not at all improbable that owing to the different circumstances of their separation from the metal the primary and secondary carbides are distinguished by certain differences in properties, partly of a chemical and certainly of a physical nature, and this has important consequences, since the physical condition of the carbide affects its tendency to decomposition.

In dealing with malleable cast-iron, the decomposition of the primary carbide during solidification of the metal does not enter into the question, since such decomposition is purposely prevented in making the iron white for malleablising; but considered generally, it will be apparent that it is this carbide which is largely responsible for the formation of most of the primary and coarser graphite in cast-irons, since it is in a structurally free condition at high temperatures; hence eminently suited for decomposition and free to be influenced by conditions favouring it. Consequently the strain under which it has been retained in that form must be very marked, and given the opportunity it will be the more readily decomposed. Moreover, as shown by the diagram, the temperatures at which the metal is annealed are such that the pearlite-iron is once more capable of dissolving a considerable quantity of its secondary carbide, if this be still free; so that in general it is the primary carbide which is more liable to decomposition, and the liberation of free carbon first occurs in the carbide eutectic areas.

The actual mechanism of this change has not yet been perfectly elucidated. It has been found by high power microscopic examination that there is a tendency for the individual small carbide crystals to coalesce prior to decomposition when free carbon is deposited from the carbide in a solidifying cast-iron. On the other hand, recent research shows that free carbon may be, and is often, liberated *in situ* on annealing white iron; in other words, that any original carbide area, after heat treatment, may be found to have been replaced by one consisting of free carbon and free iron. The conditions under which these two sets of observations were made are, however, different; and, as is well-known, the actions which are likely to occur under varying physical and chemical conditions differ considerably. Although, therefore, it may well be that on re-heating each individual carbide crystal decomposes *in situ*, yet under the conditions prevailing during the solidification of cast iron, the distinct tendency to super-cooling and the vagaries of surface tension effects on the solidifying crystallites of carbide render the coalescence and balling up of the carbide a general preliminary before the forces producing decomposition can come into full play.

Differences in molecular mobility are almost sufficient to account for the differences in the mechanism of the change; the physico-chemical conditions of the carbides are so dissimilar that the circumstances governing the decomposition of carbide in annealing processes may well differ from those occurring whilst the metal is in the process of solidification. It is hoped that further microscopic work under the necessary high powers will assist in the still fuller tracing out of this transformation.

The temperature and time factors are highly important in controlling the degree and manner of decomposition—a matter well known to the practical man. High temperature favours decomposition of the carbide, the speed of reaction increasing with the temperature. Indeed, below a certain point, carbon precipitation practically ceases.

Casting temperature has been shown to influence the decomposition, in the direction of lower casting temperature promoting carbon precipitation, a fact

probably due to the conditions which favour carbide decomposition having been already more nearly realised in such metal. The greater the chilling on casting, the smaller is the size of carbide crystal—a factor again not so favourable to decomposition as the presence of the more coarsely crystalline carbide.

The decomposition of the secondary carbide is helped by a number of interesting physical factors. Since a considerable quantity of such carbide is soluble in the iron at the annealing temperatures, it is only the excess (line b D, Fig. 1) which might be free and liable to decomposition.

The forces of migration, however, play a part in the question. By conducting the annealing at relatively low temperatures, the carbide of and around the pearlite areas tends to segregate into larger masses which are often also drawn into the larger primary carbide-areas, in which more massive condition its subsequent speed of solution in the iron may not be sufficiently rapid to prevent some prior decomposition by heat.

Another very important influence is brought to bear on the carbide; the influence of inoculation. It is well known in cases of supercooling or retention of material in a metastable condition, that the introduction of a small quantity of the stable phase may greatly encourage the retarded transformation. It is, therefore, not unlikely that the presence of primary annealing carbon already in the metal may tend to promote the precipitation of the rest or a greater portion of it.

In making malleable iron, the ideal aimed at is to so treat the raw material, the white cast iron, that the finished product is a material as closely as possible resembling wrought iron in mechanical properties.

If free carbon is to be left in the metal, it must be in such a condition as to have a minimum of weakening effect on the iron, and hence must be in as fine a form and as evenly distributed as possible, since the coarser the graphite the greater is its destructive influence on the homogeneity and continuity of the iron itself. Any circumstance favouring the formation of coarse graphite is therefore undesirable. Hence regulation of the physical condition of the free carbon is a point of exceeding importance in the annealing process, and one in which microscopic study of the mechanism of decomposition is likely to be of service.

Free carbon, when once formed, is subject to the influence of migratory forces acting in the solid metal, which tend to the gradual coalescence and growth of the constituents. Given time, together with favourable temperature, the particles of annealing carbon tend to become coarser—a tendency which is undesirable in malleablising work.

The subject of the secondary constituents in the white cast iron with respect to the annealing processes is open to investigation from the standpoint of their ultimate effect on the finished product if they are retained in the metal, and the possibility of eliminating the injurious impurities during the operation, in addition to the question of their influence on the mechanism of the process itself.

Since the ideal malleable casting approaches wrought-iron as nearly as is economically and metallurgically practicable, it is, in the first instance, desirable to introduce as little impurity as possible into the raw material; for, unless such can be eliminated during the annealing process, or its condition rendered harmless, the finished product is bound to be of inferior quality. This is particularly the case with black heart annealing. It is for this reason that phosphorus is not permissible in the white iron, since it is not eliminated by either process, whilst its destructive effects on the final product are well known. In the case of sulphur, more considerations come into question; in the black-heart process it retards the desired changes, and not being eliminated is dangerous in the malleable casting, unless the moderate quantity allowably present is neutralised by manganese. Its behaviour in the ore-annealing process is reserved for consideration in the concluding portion of this Paper. Low sulphur is naturally most advantageous, and in the American method is indeed essential. Silicon and manganese are chiefly considered from the standpoint of their influence on the mechanism of the process itself, since they are not eliminated to any important extent, and the effect in the finished product of the quantities permissible in the white iron, is rather of secondary importance. The influence of the secondary constituents on the mechanism of the production of malleable castings has, it will now be seen, to be studied through their effect on the condition of the primary and secondary carbides, and in this connection it will be of advantage to first consider how any particular constituent, such as the silicon, manganese or sulphur, has separated and is distributed, particularly with reference to the carbides. This can be more readily traced by a study of the solidification sequence, since, by ascertaining whether any secondary constituent has separated with the austenite, or has concentrated with the 1,130 degrees C. eutectic, information is given as to whether it is likely to be associated with the secondary or with the primary carbide. The investigation of this subject is as yet far from complete; but progress is being steadily made and certain facts have been fairly well established.

Silicon, as is well-known, has important influences on the carbon condition; in general, the temperature required for graphite separation is usually lowered, whilst at constant temperatures the rate at which precipitation is effected is increased progressively with silicon contents. Results of recent research indicate the manner in which varying quantities of silicon are differently distributed among the constituents of the solidifying white iron, and so are available for separately influencing the different carbides. It has been shown that some silicon is soluble in the austenite, the amount being less than 1.0 per cent.

When a molten cast-iron containing silicon below such a limiting value solidifies, the greater part of the silicon separates with the austenite as a silico-austenite, and consequently the carbide eutectic separating at 1,130 deg. may carry with it but little silicon. It follows that in the solidified and cold white iron, the primary carbide is comparatively free from silicon, but that the secondary carbide (deposited from the austenite, and thus accompanying the pearlite areas) is in some sort of association with the silicon. It has, moreover, been further shown that iron-carbide possesses an absorbing or combining power for silicon, yielding a silico-carbide which is very much more unstable than the normal iron-carbide, and therefore that when the austenite deposits its carbide (along range MP, Fig. 1), this secondary carbide carries some little silicon with it, thus separating out as a silico-carbide, endowed with a marked tendency to decompose, which is not so characteristic of normal non-silicious secondary carbide. Hence, a variety of white iron carrying up to, say, 0.8 per cent. silicon, is eminently suited for the annealing process. Uniform and almost complete deposition of free carbon is favoured, because, under these conditions, both the primary and the secondary carbides are readily and more uniformly decomposed.

In the presence of larger quantities of silicon, the silico-austenite being saturated, some is left over, and this separates with the 1,130 deg. C. eutectic, yielding a primary silico-carbide. On annealing such metal, even if it can still be obtained as white cast-iron, the tendency to decomposition becomes much more marked, so that the precipitated free carbon

may be too coarse for the production of very tough metal. High silicon in the metal renders the production of white cast-irons increasingly difficult, and by unduly hastening precipitation yields too coarse a graphite, with the possibility of introducing at the same time an embrittling and hardening influence on the liberated free iron by its own action. In white irons, silicon raises the temperature at which both the primary and secondary carbides separate from the respective solutions, thus also assisting their decomposition by exposing the structurally free carbides to higher temperatures and over longer periods of time.

The preferential absorption of moderate quantities of silicon by the austenite, thus associating some of it with the secondary carbide, appears to be of special importance in regulating the carbon precipitation. The exact method of distribution of the moderate quantities of manganese usually present in the cast-irons has not been accurately determined, and definite information on the point is desirable. Manganese undoubtedly associates itself with the primary austenite which separates during the solidification of cast-irons; the pearlite point is by the first additions lowered and with larger quantities is suppressed, thus indicating that the secondary carbide is being held firmly by the iron and in this way protected from the influences which produce decomposition. It has also been proved that the bulk of the manganese is actually associated with the carbide, occurring in the form of a double carbide of iron and manganese, which is characterised by great stability when heated; and it follows that the 1.7 to 2.0 per cent. of combined carbon existing as secondary carbide is effectively protected by the action of the manganese from the influences which tend to decomposition. It is not known how far the usual quantities of manganese present in the cast-irons are associated with the 1,130 deg. C. eutectic (producing primary carbide), although in the presence of large amounts the primary double carbide of manganese and iron is also obtained, and this is exceedingly stable.

The fact that any considerable quantity of manganese is proved capable of effectually retaining about 2.0 per cent. of the carbon in the combined form and of preventing its decomposition is sufficient to explain the desirability of reducing the amount permissible in the white iron for malleablising to moderate limits.

Sulphur appears to act in rather a different manner. When present alone it exists in the form of iron sulphide. In the quantities usually present in cast-iron it does not appear to associate itself with the austenite, but gradually concentrates in and separates with the 1,130 deg. eutectic., so that it is associated with the primary carbide, whilst, since the austenite separates free from sulphur, the secondary carbide has practically none associated with it.

Sulphur increases the stability of the carbide, the action being to a large extent a physical one, though the actual mechanism is not yet perfectly clear. Research has indicated that the sulphide tends to emulsify the minute crystals of carbide, a condition favouring super-cooling and retention of metastable forms, retarding their coalescence and thus opposing the forces favouring precipitation of carbon, whilst it has also been suggested that the sulphur, in very small quantities, enters into combination or solution with the iron carbide to form a sulpho-carbide which is more stable than the normal carbide itself.

The ultimate effect of the sulphur thus tends to increase the stability of the carbides and to prevent or retard carbon precipitation, because the primary carbide, which is otherwise more liable to decomposition, is now rendered more stable by its preferential association with the sulphide, whilst the secondary carbide, which is otherwise not so prone to decomposition, is now more protected, indirectly, owing to the absence of free carbon which might otherwise promote decomposition by inoculation. In all the above cases the action indicated is assisted by the diffusing powers of the various constituents.

The foregoing statements have reference to the influence of the constituents when present singly; the simultaneous effect of two or more of these impurities is necessarily more complex, and much research is required before exact knowledge is obtained. The joint effects of manganese and sulphur are, however, fairly well known; in suitable proportions the elements combine, forming a practically inert material which exerts but little influence on the carbon deposition, whilst excess of either constituent exercises its own particular retarding action.

Of the relations of sulphur and silicon in reference to the solidification sequence and ultimate distribution very little has been positively determined.

The English or ore-annealing process has not received the same amount of study from the scientific point of view as has the black heart; and the actions in question are rather more involved, since it is not only the transformation of carbide to free carbon, but also the elimination of some of the carbon through the agency, direct or indirect, of the ore, which is involved. The ore annealing process is particularly suitable for white irons containing sulphur, since the influence of this impurity tends to prevent the carbon precipitation in black-heart annealing, whilst by the treatment in hematite ore, carbon is to some extent eliminated independently of the sulphur, which is itself often partly removed; the quantity remaining is, moreover, held to have a much less harmful influence than on a black-heart casting, where only minute amounts are permissible.

Recent research on a non-sulphury iron has indicated that a precipitation of carbon from the carbide is a preliminary to its removal in ore-annealing under the conditions of the experiments; and that the malleablising process proceeds in two stages, the first being carbon precipitation, and the second its elimination. It was also found that the whole of the action was not attributable to direct action of the ore at the surface, but by action penetrating inwards; in other words, the carbon did not travel to the oxidiser, but the oxidiser towards the carbon, suggesting action by gases; and that the hematite acted indirectly only, by supplying the oxidising gas.

It is very probable that the mechanism involved in the production of some of the more sulphury malleable castings is somewhat different and more complex than this. The oxide appears to absorb sulphur from the metal in immediate contact with it, by the removal of which the carbon change becomes possible within a restricted area, resulting in local deposition of annealing carbon, the removal of which by the oxygen and CO_2 is now able to proceed. The well-known diffusive power of the sulphides and of the carbon in iron, proceeding outwards, and the inward diffusion of the oxidising gases, lead to the production of a progressively thickening outward layer of malleable iron, enclosing a core in which sulphur and combined carbon may still remain in reduced quantity.

In this connection reference must be made to the views embodied in a recent Paper to the Foundrymen's Association by one of our best-known authorities, in which it was suggested that the elimination of carbon took place whilst it was still in combination with iron, and commenced even at such a comparatively low temperature as 750 deg. C., the elimination being brought about by interaction between the carbide and the oxidising medium. The impoverishment in carbon of the outer layer of the casting leads to a diffusion of more carbon from the interior, and in this way the elimination gradually proceeds. It was held that

decarburisation was the first stage in malleablising by ore-annealing, and that carbon precipitation followed when temperature and other conditions became suitable.

Both these views, though conflicting, have much evidence to support them, and both present reasonable explanations of well-known facts. It appears, indeed, to be not improbable that, as is the case in many similar instances of apparent divergence in expert opinion, the truth of the matter is embodied in a compromise between the two views, and that possibly both series of reactions proceed together through the metal.

Discussion.

The PRESIDENT, opening the discussion, said the subject of malleable iron was particularly interesting because its production was a growing industry.

MR. A. H. HIORNS remarked that it was quite true that malleable iron was being more and more used. The exhibition of a diagram showing the presence of 4.3 per cent. of carbon indicated certain new departures. He had never heard of cast iron containing more than that proportion unless special elements were present, and he could not follow the reasoning of the second part of the diagram, because he held that if there were more than 4.3 per cent. of carbon, the excess separated out in the form of graphite. Apparently, from the diagram, 7 to 8 per cent. of carbon was neither impossible nor ridiculous, as he formerly supposed. He was glad to see the point about the size of the crystals so clearly brought out. It was clear that large crystals indicated a weakening condition, and perfect malleablising was dependent on crystals of the proper size. At the lower temperature at which iron was malleablised, they got secondary carbide separated from the smaller crystals. They generally found with regard to alloys that if they got an element which separated in a free form in a finely divided state it was more or less equally distributed all over the alloy, and the alloy was very much better than when one of the constituents segregated in large masses. In the latter case the general result was that the metal was weaker. That was especially the case with lead. Generally, fine particles of carbon constituted an essential element of strength. The idea of inoculation was very true as applicable to metals, and he had known a kind of disease communicated to lead in that way.

MR. W. H. COLE said he could not detect any difference between the primary and secondary carbide. The microscope showed no line of demarcation. From what was known as the four-phase rule, they would conclude that the two carbides were identical.

MR. R. BUCHANAN said he would like some definition of such terms as "super-cooling," "stable" and "meta-stable."

MR. HAILSTONE associated himself with Mr. Cole's remarks on the primary and secondary carbides.

MR. SLEIGH, as one engaged in the malleable iron trade, called attention to the increasing use of such metal for copper-plated and bronzed goods. His firm had bought large quantities for such purposes, and found great difficulty in getting castings of satisfactory quality. The material was sometimes too hard to take a twist drill, while small holes in the casting and "searing" were also very serious defects.

MR. J. H. WESTWOOD wished to know why new ore should not be used every time instead of combining new with old ore, as was done in many foundries?

MR. LEVY, replying on the discussion, explained the term "super-cooling" as the cooling to an abnormal degree, as in the case of water which could be cooled below the freezing point without freezing actually taking place. Super-cooling of metal was cooling below the temperature at which change took place. The effect of silicon had been very ably worked out in a paper recently given before the Iron and Steel Institute by Gontermann. As to the primary and secondary carbides, when they had carbides separating out at widely different temperatures, they must have quite different conditions of the carbides. Other terms used were fully dealt with in recent papers, especially in Gontermann's paper. As to the question of old as compared with raw ore, it was customary to use old ore to dilute the action of raw ore, which was often found too vigorous.

A hearty vote of thanks was accorded Mr. Levy for his paper.

British Foundrymen's Association: Birmingham Branch.

Annual Meeting and Election of Officers.

The concluding meeting of the session in connection with the Birmingham Branch of the British Foundrymen's Association was held on Saturday, May 27th, in the Technical School, Suffolk Street, Birmingham. The more technical proceedings were preceded by the holding of the annual meeting, over which Mr. C. Heggie presided, in the absence, until some time later in the evening, of the President, Mr. A. H. Hiorns.

The annual report read by the Secretary of the Branch, Mr. G. Hailstone, showed a present membership of 194, comprising hon. members, members, associate members and associates, being a total increase of 61 on the year. The Chairman expressed the belief that a further substantial advance would take place during the present year. The accounts showed a total expenditure of £13 18s. 9½d., leaving a balance in hand of a few shillings. Seven ordinary meetings had been held, and three visits to works had taken place.

On the proposition of the Chairman, Mr. H. L. Reason was chosen President for the year, and hearty thanks were accorded to Mr. A. H. Hiorns for his services in the chair.

Messrs. C. Heggie and W. Gale were chosen vice-Presidents, Mr. G. Hailstone was re-elected Secretary and Treasurer, and the following were chosen to constitute the Council:—Messrs. R. Buchanan, F. J. Cook, J. Bullock, D. Dalrymple, H. Pemberton, J. J. Howell, J. H. Toy, Robinson, W. Lisle, and W. H. Jacques. It was decided that in future a councillor failing to attend any one of the meetings during the year should not be eligible for re-election.

Replying to Mr. Buchanan, the Secretary announced that several papers for next session had already been arranged. They were hoping to get a paper on "Chilled Rolls" from a gentleman in Middlesbrough; a second on "Match-plates"; and a third on "Physical Test Results." One night was to be devoted to the discussion of an article in the "Foundry Trade Journal," and another to a general discussion. They hoped to have a paper from Mr. W. H. Hatfield, of Sheffield, on "Carbon in Iron," and other papers on "Vanadium in Cast Iron" and "Pattern-making." In all, seven papers had been promised.

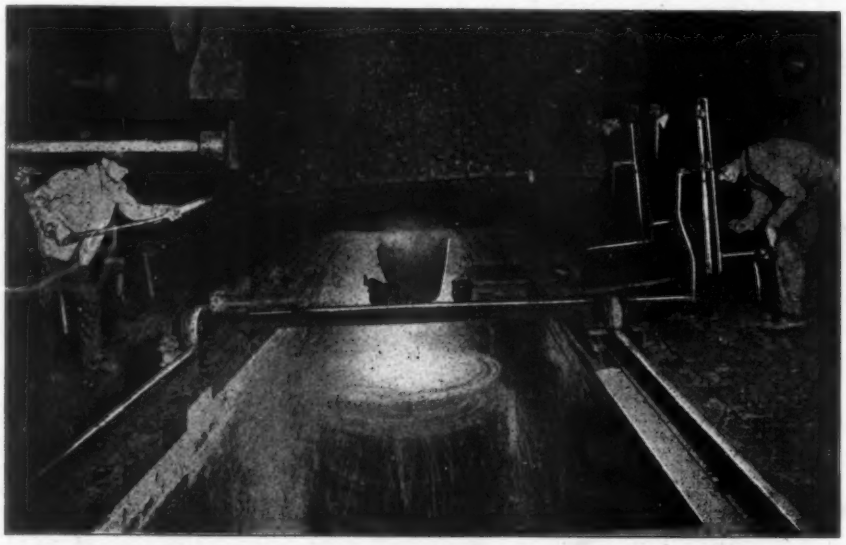
The remainder of the evening was devoted to the reading and discussion of a paper by Mr. Donald M. Levy, M.Sc., Assoc.R.S.M., on "The Mechanism of the Production of Malleable Castings," which paper and discussion will be found on pages 321 *et seq.* of this issue.

A Novel Method of Casting Steel Car Wheels.

In a recent issue of "The Iron Age" is described a method of casting steel car wheels invented by Mr. J. C. Davis, assistant to the first vice-president of the American Steel Foundries. The object of the invention is to produce a cast-steel wheel for railway work having the strength of the steel-tyred wheel and the wearing qualities of the chilled cast-iron wheel. The investigations which led to Mr. Davis' invention date back 10 years, when the inventor was on a train which was derailed by a broken flange of a cast-iron wheel. Chemical and microscopic examination revealed sulphur segregation at the point of failure. The first experiments were with a blank gear pattern. In these it was discovered that by adding ferro-manganese to the molten steel when it was poured, a casting of any desired degree of hardness could be produced. The problem was, however, to get the necessary hardness where it was wanted in the casting, and at the same time leave the central part soft enough to be machined. This was finally solved by revolving the mould at the time of filling and introducing the ferro-manganese in such a way that it would affect only the outer portion of the wheel. Thereupon special apparatus and moulds suitable for full-sized wheels were prepared and the experiments continued on a more elaborate scale with proper safeguards at each step.

Formulas have been made for every step from the melting of the material in the furnace to the final machining of the wheel. The methods of determining and controlling temperatures are such as eliminate dependence on human agency and insure uniformity in results. The moulds are dried in ovens, the temperature of which is regulated by the use of special pyrometers. The pouring of the moulds is an operation of particular interest. When ready for filling they are mounted on tables, which are made to revolve as the molten metal is being poured into them. The first metal to enter the mould is treated with ferro-manganese, introduced by compressed air as the metal passes from the ladle to the mould. The steel thus treated is followed up immediately by soft steel, which forms the plate and hub of the wheel. The revolution of the mould makes it possible to produce regularly in an integral wheel a manganese steel tread and flange with a soft steel hub. The manganese, being heavier than steel, is drawn by the centrifugal motion to the outer parts of the mould.

The flasks, as the moulds are being prepared, stand on tables consisting of parallel beams, this arrangement facilitating the handling. The moulds are set by cranes in the pit in which they are poured, two moulds being in place in the pit at one time. While one is being poured the other is removed by an independent hoist and an empty mould set in its place. The steel from the open-hearth furnaces is tapped into a 25-ton ladle, which is carried to the pit by a travelling crane. The steel is poured from the bottom of the ladle, the flow of metal being regulated by a cone-shaped cup carried by a truck running on tracks laid across the pit, as shown in the illustration herewith. As the moulds are poured three cranes are in use. One carries the ladle, and on either side a crane takes out a flash that has been poured, or puts in one ready for the next pouring. On their removal from the moulds the wheels are given an annealing, the temperature being regulated by a pyrometer. The object of this treatment is to secure a fine molecular structure and eliminate internal strains. From the annealing furnaces the wheels are taken first to a hydraulic straightening press and then to a boring mill where the wheel fit is accurately rough-bored to within ¼ inch of the finished size. It then passes to a grinding machine, where the tread and the throat of the flange are ground. Following the grinding the wheels are again heated and water tempered, this operation giving a denser metal in the rim of the wheel and imparting toughness.



CASTING CAR WHEELS; THE MOULD ON THE REVOLVING TABLE DURING POURING.

The Growth of Cast Irons after Repeated Heatings.*

PARTS II. III. AND IV.

By H. C. H. Carpenter, M.A., Ph.D.

The following Paper contains an account of an investigation which has arisen out of one published by Professor Rugan and the author.† In the previous Paper the influences on the growth of cast irons of carbon, silicon, gases dissolved in the irons, and those penetrating from outside, were established, but the effects of sulphur and phosphorus were not determined, and that of manganese only in part. As these three elements are regular constituents of all cast irons, their influence has to be estimated before a complete theory of "growth" can be enunciated. This has now been done, and the data and conclusions therefrom constitute the subject-matter of the first-sub-section of this Paper—namely, Part II. This section also contains calculations of the approximate growth that may be expected in grey cast irons whose chemical composition is known.

The next section, Part III., is of purely scientific interest, and is here omitted as not being of direct interest to those who are only concerned with the practical aspects of the investigation. It deals with the growth of the grey irons, N-S inclusive, described in the previous Paper, when repeatedly heated *in vacuo*, and the bearing of this on the theory of their growth in air.

The final section, Part IV., contains an account of experiments, based to some extent on information given in the discussion of the previous Paper, and undertaken with the object of finding a commercial alloy whose growth after repeated heatings is negligible, and which may be successfully used for annealing ovens, rolls, ingot moulds, etc. From the practical standpoint this is the most important section of the Paper.

PART II.

(*a*) *The Influence of Phosphorus on Growth.*—Taking alloy N as the base, three alloys were cast with increasing phosphorus, viz., X, Y, and Z. Their chemical composition and that of N are given in Table I.

TABLE I.

Alloy.	Total Carbon.	Graphite.	Combined Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
N ...	3.92	3.34	0.64	1.07	0.25	0.010	0.018
X	3.98	3.39	0.59	1.04	0.20	0.015	0.287
Y	3.90	3.10	0.80	0.99	0.20	0.015	0.432
Z	3.95	3.61	0.34	1.13	0.20	0.015	0.853

It will be seen that with the exception of phosphorus, the percentages of the various constituents are nearly constant. These bars were grown under the same conditions as N, and the results are given in Table II.

These results show that phosphorus, which is present, of course, as a phosphide eutectic, not only does not cause an increase in ultimate growth, but a marked diminution, viz., between 2.5 and 4 per cent. for corresponding irons. Moreover, the phosphoric irons grew more slowly, and their rate of growth was more regular than that of N. It will be

TABLE II.

Alloy.	Heats required for Ultimate Growth.	Increase in Volume.	Increase in Weight.
		Per cent.	Per cent.
N	18*	16.10*	0.7*
X	25	13.61	1.17
Y	28	10.97	0.84
Z	29	13.31	1.31

* Mean of figures for N and NN.

observed that the increase in weight was rather greater. This is probably due to the phosphide eutectic hindering the burning of carbon, and not to an oxidation of the phosphide. The latter would almost certainly cause an increase in volume which is not found. Microscopic examination of the original and fully-grown bars showed that no oxidation of the phosphide had occurred.

(*b*) *The Influence of Sulphur on Growth.*—After examining a large number of typical analyses of commercial grey irons, it appeared unnecessary to undertake any special experiments as to the effect of this element. The amount present is invariably small, rarely reaching 0.2 per cent. Taking this into consideration, together with the tendency of sulphur to keep carbon in the combined state in irons, it is quite certain that this element does not contribute appreciably to growth.

(*c*) *The Influence of Manganese on Growth.*—Some information as to this can be obtained by an examination of the growths obtained with alloys J, K, L, and M in the previous investigation. Table III. gives their

TABLE III.

Alloy.	Carbon per cent.	Silicon per cent.	Manganese per cent.	Percentage Growth.		Number of Heats required for Ultimate Growth.
				Found.	Calculated.	
J ...	4.60	0.79	1.26	12.65	11.9	50
K ...	3.90	0.69	1.09	10.35	10.4	58
L ...	3.60	0.65	1.02	8.70	9.8	68
M ...	3.02	0.20	0.86	4.3*	7.5	58

* Mean value of M and MM.

compositions and ultimate growths. It also contains what have been called the "calculated" growths. The figures in this column have been obtained by prolonging the curve of growth due to silicon to zero, and reading off the approximate growths corresponding to the silicon percentages of J, K, L, and M. For this purpose Fig. 1 has been reproduced from the previous Paper.

It will be seen that only in the case of J is the "found" higher than the "calculated" value, viz., by 0.75 per cent. From these results it would appear that when silicon does not exceed 0.7 per cent., manganese not only does not contribute to growth, but tends to

* Paper presented before the Iron and Steel Institute, May, 1911.
† "Journal of the Iron and Steel Institute," 1909, No. II., pp. 29–143. (See FOUNDRY TRADE JOURNAL, November, 1909.)

diminish it; further, that the lower the silicon the greater the diminution. Even in the case of J the rate of growth is greatly retarded, fifty heats being required for the attainment of full growth, as compared with about twenty for alloys N and O.

These conclusions have been entirely confirmed by several lengthy series of experiments described in Part IV., and manganese must be regarded both as retarding the rate of growth in all cases, and diminishing the absolute amount in the majority of cases.

(*d*) *The Influence of Dissolved Gases on Growth.*—This was estimated for alloys N and S in the previous investigation. It has since been determined for the entire series under the same experimental conditions, and details are given in Part III. of this Paper. The alloys were heated *in vacuo* at 800—900 deg. C. until their volume was constant. During this treatment gases, whose volume varied between 0.76 and 1.60 per cent. of that of the alloy

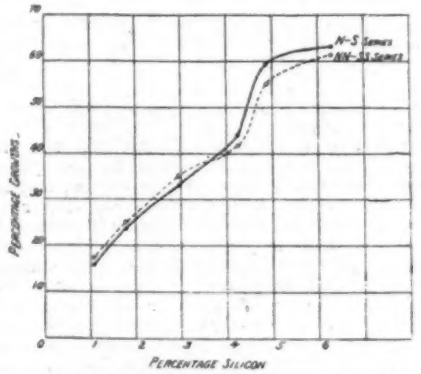


FIG. 1.—ALLOYS N TO S. CURVES ILLUSTRATING THE RELATION BETWEEN PERCENTAGE GROWTH AND PERCENTAGE SILICON.

experimented with, were evolved. Table IV. gives the results. For purposes of comparison the mean percentage growths in air have been added.

TABLE IV.

Alloy.	Total Carbon.	Combined Carbon.	Silicon.	Change of Volume *in vacuo*	Volume of Gas Evolved.	Growth in Air.
	Per cent.	Per cent.	Per cent.	Per cent.		Per cent.
N ...	3.98	0.64	1.07	+11.10	1.17 times	16.1
O ...	3.98	0.68	1.79	+ 2.16	1.48 ,,	24.0
P ...	3.79	0.30	2.96	+ 2.73	0.76 ,,	33.6
Q ...	3.76	nil	4.20	− 0.19	1.60 ,,	42.8
R ...	3.79	,,	4.83	+ 0.15	1.29 ,,	57.4
S ...	3.38	,,	6.14	− 0.01	1.11 ,,	67.7

It will be seen that under this treatment alloys N, O, and P all grew *in vacuo*, whereas Q, R, and S hardly changed in volume, two of them showing a slight contraction and the third a small expansion. From a practical standpoint, however, their volume changes may be regarded as negligible. Of the three alloys which grew, N showed much the greatest expansion. Even allowing that, in the experiment, all the combined was changed into temper carbon, this will not account for more than about 1.1 per cent. growth, so that the dissolved gases must be regarded as causing a growth of about 10 per cent. In the alloys O and P, which are much more "open" irons, the growths due to this agency are between 1 and 2 per cent. It is quite clear from these experiments that in "close" grey irons, which do not contain more than about 1.2 per cent of silicon, the pressure of dissolved gases is responsible for a good deal of the growth observed.

The "Growths" to be expected on Heating Grey Cast Irons to Redness.—In these irons the following structural constituents may be present:—(1) A solid solution of iron silicide, and possibly manganese silicide, in iron. This will be called "silico-ferrite." (2) Graphite. (3) Combined carbon, either as iron carbide or as iron manganese carbide, according to the amount of manganese present. (4) Phosphide eutectic. (5) A small quantity of either iron or manganese sulphide, or both. (6) Dissolved gases, consisting principally of hydrogen and some nitrogen.

The influence of each of these factors has now been, as far as possible, determined by the author, and an attempt will be made to estimate their combined effect on the growth of any given iron. It may be well to state at the outset that the foregoing investigations lead to the conclusion that there is no such thing as a grey iron which will not grow when repeatedly heated to redness, in the presence either of furnace gases or air. This fact must be frankly recognised. All that can be done is to estimate the growth that may be anticipated in an iron whose chemical composition is known.

No. 1 is undoubtedly the most potent factor in causing growth. No. 2 is essential to growth, but its action appears to be indirect, viz., by acting as the channel for the penetration of gases into the iron. No. 3 is only a slight contributory cause of the growth of a grey iron, and, at the very outside, is probably not responsible for more than 1.5 per cent. No. 4 not only does not contribute to growth, but diminishes the rate and the absolute amount. No. 5 has a retarding effect on growth. No. 6 is a notable factor in the growth of "close" grey irons, but not of "open" ones.

The effects of Nos. 1 and 2 can best be considered together. It was shown in the previous research that "the main cause of growth is the disintegration of the material caused by the oxidation of the silico-ferrite." The volume increase consequent on the reaction

$$FeSi + O_2 = FeO + SiO_2$$

is no doubt definite, and could be determined if this were the only change. But it was also shown that, in addition, some iron is oxidised. The amount of this is variable, and will depend on the distribution of the graphite and the consequent avenues for oxidising gases. The smaller the graphite plates the greater the surface they will expose, and the greater will be the oxidation. The distribution and character of the graphite will depend on the composition of the alloy, the temperature at which it is cast, and the rate of cooling. Accordingly the oxidation of the iron must be regarded as a variable whose influence cannot be numerically estimated. As regards No. 3 it is safe to conclude that at the outside it will not cause a growth of more than 1.5 per cent. No. 4 will tend to diminish the growth by about 3 per cent. if the phosphorus reaches 0.3 per cent. Higher percentages will tend to diminish the growth still more. As mentioned, the influence of No. 5 is small, because the absolute amount of sulphide present is small. No. 6 has no influence on an iron containing more than 3 per cent. of silicon. Between 1.75 and 3 per cent. of this element, dissolved gases may cause a growth of from 1 to 2 per cent. Its influence is much more powerful when the silicon does not exceed 1 per cent., and in such cases it may be responsible for a growth of at least 10 per cent.

Taking everything into consideration, and having regard to the fact that the great majority of commercial grey irons contain between 1 and 3 per cent. of silicon, this element must be regarded as by far

the most potent influence in the growth of grey irons, and the best general expression of the connection between growth and composition is Fig. 1, which takes silicon into account and ignores all other constituents. Table V. has an interesting bearing on this matter.

TABLE V.

1. Alloy.	2. Silicon.	3. Mean growth	4. Average calculated for 1 per cent. of silicon.
	Per cent.	Per cent.	
N	1.07	16.1	15.0
O	1.79	24.0	13.4
P	2.96	33.6	11.4
Q	4.20	42.8	10.2
R	4.83	57.4	11.9
S	6.14	67.7	11.0

The values given in column 4 appear to show that up to 4 per cent. silicon has a gradually diminishing effect on growth. In reality, this is probably not the case. The lower members of the series, viz., Q, R, and S, give the silicon effect most nearly, because the values obtained with them are not complicated by growth due to the pressure of dissolved gases, or the conversion of combined to free carbon. The mean value in these three cases is 11 per cent. of growth per 1 per cent. of silicon. This may be regarded as the nearest approximation possible to the pure silicon effect, but there is no doubt that some of it is due to the oxidation of iron. With silicon diminishing below 3 per cent., the two above-mentioned complications begin to assert themselves, particularly the gas effect in the low-silicon irons, and cause the silicon effect to appear larger than it really is.

The author would suggest the following test as the simplest and most rapid for forming an opinion as to the growth that is liable to take place in any particular grey iron: Estimate the silicon, and then read off the approximate growth from the data in the table given at the end of the Paper.

If the iron contains 0.3 per cent. of phosphorus and upwards, the growth will be from 2.5 to 4 per cent. lower than the above figures, and if more than 0.5 per cent. of manganese is present, the rate of growth will be diminished while the amount of growth will be to some extent lessened.

The author would, however, venture to caution readers against too strict an application of this test, and to emphasise the fact that the table is only an approximation. It is impossible to make allowances for variables such as the temperature of casting the alloy, its size, and the rate at which it cools, each of which will have its effect on the physical and possibly chemical condition of the structural constituents in the casting, and particularly on the retention of gases. At the same time it appears to him as the nearest general approximation that can be made, and variations from it will probably not exceed 10 to 15 per cent. of the absolute value, and may be smaller.

The general theory of growth outlined in the first Paper, although enunciated at a time when all the possible factors of influence had not been fully considered, still holds the field. It requires to be slightly supplemented, but not modified, as a result of these later experiments. Neither phosphorus, sulphur, nor manganese contribute to growth. The only addition which the author desires to make arises out of a suggestion made both by Professor Turner and Mr. Saniter in the discussion of the first Paper. The former said, "If they imagined the iron in those samples to be in a very soft state, and to be surrounded by a hard skin, it was quite conceivable to him that the particles of iron, when heated, might expand at the moment of heating, and when they wanted to shrink back they could not get back." The latter said, "Every time it" (that is the iron) "was annealed and expanded, whether by oxidation of the silicon or by a slight oxidation of the iron, the presence of those bodies again prevented it from contracting to its old size when it was cooled and that went on when it was again stretched by heating. He thought that was the explanation of the authors, but he did not think it had been worked out as far as it might have been." This aspect of the *modus operandi* of the oxidation of silicon and iron in causing growth is one with which the author entirely agrees. It follows from this reasoning that after a few heats such irons would be under considerable tension at the ordinary temperature. This has the merit of accounting to some extent for the cracking which took place in the specimens, and for the rapid deterioration of their mechanical properties.

Part IV.—Alloys of Small or Negligible Growth.

In the concluding paragraph of the Paper by Professor Rugan and the author, the following recommendation was made:—"The authors have no hesitation in recommending that white irons should be tried for annealing ovens, instead of grey. The most suitable composition appears to be an iron with about 3 per cent. carbon, *e.g.* C, and as few impurities as possible. Of these silicon is the most important, and should not exceed 0.2 to 0.3 per cent. This iron would probably shrink slightly on repeated heating. The reason why an upper limit of 3 per cent. of carbon is suggested, is that white irons higher in carbon will tend to deposit temper carbon. Where this is the case the material will begin to grow. Even so, however, the growth will never be as much as in a grey iron. It is possible that an oven constructed of white iron may prove to be unsuitable because it may crack on heating. Should this difficulty arise, it may perhaps be overcome by modifying the design."

This recommendation was criticised on two grounds. (1) It was pointed out that commercially it would be difficult to obtain an iron with so low a percentage of silicon, and that about 0.5 per cent. was the maximum practice figure. (2) It was urged that it would be very difficult to prevent such an iron from cracking on heating. Thus Mr. Fletcher (Dudley) wrote:—"The suggestion that an alloy low in silicon, and having a carbon content not exceeding 3 per cent., could be used for such articles as annealing pots was valuable. It would be interesting to hear that such an alloy could be employed successfully. Castings of that composition, whether made in chills or sand, had a pronounced crystalline structure, the crystals arranging themselves at right angles to the cooling surfaces of the mould, and unless free from sharp angles of uniform thickness and well fed and clean at the running gits or feeders, such castings would crack when subjected to rapid heating up from the cold state."

Again, Mr. Cosmo Johns (Sheffield) wrote: "Using a low-silicon iron, would, from the authors' results, give a material that would not 'grow,' but such a white iron could only with great difficulty be treated so as to convert its combined carbon into the graphitic form, and would probably have fractured before that change had been accomplished. . . . . The chief difficulty seemed to lie in overcoming the liability to fracture during the earlier heatings of those low-silicon alloys."

In making the above recommendation the authors took it for granted that temper carbon should not be deposited on heating. Otherwise growth will certainly follow and perhaps cracking. Criticisms 1 and 2 are, however, to a great extent met by the contribution

of Mr. Hatfield (Sheffield) to the same discussion. He wrote, "It might be of interest, in confirmation of the authors' views, to record an incident connected with the use of chills in the iron foundry. At the works with which he (Mr. Hatfield) was connected, the same grey cast-iron chills had been, some years before, used repeatedly in producing one particular series of castings. As time went on it was found that the dimensions of the casting in the neighbourhood of the chill showed considerable variation, and the trouble was directly traced to that characteristic of cast iron which had been so thoroughly investigated by the authors. It would be interesting to know that the solution of the difficulty had been found by using white-iron chills low in silicon, which retained their original dimensions even after considerable service."

At the author's request Mr. Hatfield has kindly informed him of the composition of these white-iron chills. This information is confidential, but it is permissible to state that the chemical analysis is not very different from that recommended by the authors, that these moulds do not crack under ordinary usage, and that there is no appreciable precipitation of carbon. Further, the test of this alloy in the form of a chill mould into which hot metal is poured and which therefore is very rapidly heated, is much severer than in the form of an annealing oven, which is only gradually heated. It seems almost certain that any material that will stand the former will also stand the latter test. But there is no getting away from the fact that the alloy is brittle.

The authors' joint investigation showed that alloy I, which is really a mild steel, did not grow at all on repeated heating, but tended to shrink slightly. The composition of this is:—Carbon 0.15 per cent.; silicon 0.186 per cent.; manganese 0.15 per cent.; sulphur 0.040 per cent.; phosphorus 0.017 per cent. The same holds for alloy H, which has 0.55 per cent. of carbon, but is similar in other respects. These are ductile materials, particularly I, and on this account are undoubtedly to be preferred to C. Owing, however, to their high melting-points, they would be much more costly materials, and the practical problem has been to find a white iron which would be as cheap to make as C, and which is, if possible, as ductile as I. Strictly speaking, no doubt, this is impossible of attainment.

In his contribution Mr. Fletcher refers to his having used with success an iron containing about 3 per cent. of carbon, 0.6 to 0.7 silicon, and 0.5 manganese for the faces of shingling hammer tools. This is the same carbon percentage as that recommended by the author, but silicon and manganese are appreciably higher. He says, "Ordinary grey castings 'grew' quickly on the face and rapidly disintegrated. The difficulty of white-iron castings was that they were liable to be brittle. The presence of manganese modified the action of the silicon in such castings for the reason that graphite formation was hindered and . . . the presence of the 0.5 manganese permitted silicon up to 0.6 to 0.7 per cent to be used to the benefit of the castings, which did not disintegrate so rapidly and were less brittle." These tool faces were grey when slowly cooled, white if chilled, but close-grained however slowly they were cooled. It is clear from these facts that manganese can toughen to some extent a brittle white iron.

The experiments with alloy MM, quoted in the first Paper, have an important bearing on the estimate of the influence of manganese. This alloy contained 3.02 per cent. carbon, 0.50 silicon, 0.86 manganese, and thus resembles Mr. Fletcher's alloy to a considerable extent. On heating it contracted for about 10 heats and then grew slowly, attaining a maximum growth of 2.54 per cent. only after about 50 heats. In doing so it deposited temper carbon. This is a comparatively small and also a slow growth. Taking these facts into consideration, it appeared that the influence of manganese should be more thoroughly investigated, and that alloys containing about 2.5 per cent. of carbon, 0.5 to 0.6 per cent. of silicon, and varying amounts of manganese might be expected to furnish one of even smaller growth than MM, and, owing to the lower carbon, one of still greater toughness. It was of course recognised that the dropping of the carbon meant some rise in the melting-point, and that the alloys would be a little more expensive to found. The problem, however, was one that called for compromise, and it was obvious that, in spite of the increased cost of melting, the materials would be must cheaper than mild steel.

Three alloys were ordered from Sir W. G. Armstrong, Whitworth & Company. The actual compositions came out as in Table XVI.

TABLE XVI.

—	No. 1.	No. 2.	No. 3.
	Per cent.	Per cent.	Per cent.
Carbon	2.40	2.40	2.25
Silicon	0.485	0.471	0.406
Sulphur	0.01	0.01	0.01
Phosphorus	0.01	0.01	0.01
Manganese	0.51	0.735	0.935

These figures were sufficiently near the desired ones for the intended experiments, although in No. 3 carbon, silicon, and manganese were all a little lower than they should have been. All three irons, which had been cast in sand, were white irons. At the outset it was considered important to get some idea of their toughness. The turner who machined the specimens reported that "they turned like very tough malleable irons." Further, the author found it very difficult to fracture bars by hammering them, and that in fact they could be indented to a considerable extent during this treatment. They were thus shown to possess decided toughness. The tenacity tests on the specimens (0.564-inch diameter) gave the following results:—

No.	Ultimate stress. Tons per square inch.
1	19.92
2	20.20
3	22.00

A distinct rise in mechanical strength with increased manganese was thus shown.

Machined bars of the three alloys were heated in a muffle furnace for four-hour periods at 850 deg. to 900 deg. C. Volume measurements were made from time to time, and 150 heats were carried out, with the results shown in Tables XVII. to XIX.

TABLE XVII. No. 1.

Carbon ... ... 2.40 per cent.
Silicon ... ... 0.485 ,,
Manganese ... ... 0.51 ,,

Length. Inches.	Diameter Inch.	Volume. Cubic in.	Change. Per cent.	Weight. Grammes	Change. Per cent.	Heat No.
6.0048	0.9223	4.0124	—	486.09	—	—
6.0000	0.9225	4.0093	- 0.08	485.77	- 0.07	11
6.0223	0.9288	4.0789	+ 1.66	484.95	- 0.23	27
6.0580	0.9293	4.1073	+ 2.36	484.58	- 0.31	41
6.0800	0.9336	4.1617	+ 3.80	484.31	- 0.37	56
6.1051	0.9378	4.2174	+ 5.11	483.95	- 0.44	74
6.0832	0.9386	4.2097	+ 4.92	483.55	- 0.52	100
6.0856	0.9406	4.2270	+ 5.35	482.93	- 0.65	126
6.0694	0.9513	4.3129	+ 7.49	481.90	- 0.86	151

TABLE XVIII. No. 2.

Carbon ... ... 2.40 per cent.
Silicon ... ... 0.471 ,,
Manganese ... ... 0.735 ,,

Length. Inches.	Diameter Inch.	Volume. Cubic in.	Change. Per cent.	Weight. Grammes	Change. Per cent.	Heat No.
6.0068	0.9203	3.9970	—	474.87	—	—
6.0017	0.9204	3.9935	- 0.09	479.48	- 0.08	11
6.0223	0.9242	4.0391	+ 1.05	478.62	- 0.26	27
6.0470	0.9258	4.0708	+ 1.85	478.23	- 0.34	41
6.0625	0.9294	4.1134	+ 2.90	477.93	- 0.40	56
6.0774	0.9334	4.1581	+ 4.03	477.44	- 0.51	74
6.0675	0.9348	4.1629	+ 4.15	477.08	- 0.58	100
6.0667	0.9422	4.2290	+ 5.80	476.52	- 0.70	126
6.0560	0.9440	4.2391	+ 6.06	475.72	- 0.87	151

TABLE XIX. No. 3.

Carbon ... ... 2.25 per cent.
Silicon ... ... 0.406 ,,
Manganese ... ... 0.935 ,,

Length. Inches.	Diameter Inch.	Volume. Cubic in.	Change. Per cent.	Weight. Grammes	Change. Per cent.	Heat No.
5.9993	0.9183	3.9727	—	478.42	—	—
5.9942	0.9177	3.9640	- 0.22	478.18	- 0.05	11
5.9965	0.9182	3.9691	- 0.09	477.50	- 0 19	27
6.0116	0.9200	3.9959	+ 0.58	477.08	- 0.28	41
6.0241	0.9214	4.0156	+ 1.08	476.75	- 0.35	56
6.0456	0.9213	4.0282	+ 1.40	476.44	- 0.41	74
6.0588	0.9210	4.0369	+ 1.61	476.07	- 0.49	100
6.0698	0.9241	4.0692	+ 2.43	475.54	- 0.60	126
6.0748	0.9267	4.0956	+ 3.09	474.68	- 0.78	151

Fig. 2 shows the results graphically. The growths recorded may be regarded as maximum values. From heat 56 onwards scale formed on the bars. This affects the accuracy of the measurements to an increasing extent as the heats progress, and tends to produce high results, so that the figures for growth appear

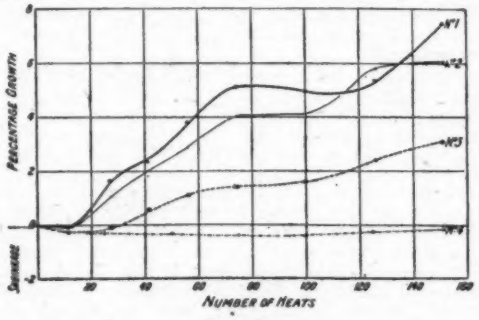


FIG. 2.

somewhat larger than they really are. As was noticed in the previous research, the bars grew fastest at the end nearest the gate. None of the bars cracked during the treatment. It will be observed that at the outset each bar contracted slightly, but afterwards began to grow.

No. 1 contracted for about eleven heats, then grew fairly regularly until the 76th heat, and afterwards contracted slightly. At heat No. 126 its growth was 5.35 per cent., and then a further growth set in. After 151 heats its growth was 7.49 per cent., and was not yet finished.

No. 2 behaved somewhat similarly, but grew less, 6.06 per cent. growth being recorded after 151 heats.

No. 3 grew very markedly less than Nos. 2 and 1. After 100 heats its growth was only 1.61 per cent., and after 151 heats only 3.09 per cent.

It will further be observed that the growths are in the inverse order of manganese contents, and that comparing these results with MM, No. 1 grew very slightly more, No. 2 less, and No. 3 considerably less. These results, whilst not constituting a solution of the problem, were distinctly promising, for they indicated that manganese was the key to the situation, and that by increasing this still more an alloy of negligible growth would be obtained. Accordingly, a fresh alloy was cast by Sir W. G. Armstrong, Whitworth & Company at the author's request, the following table giving the composition asked for and actually obtained:—

Alloy No. 4.

—	Desired composition.	Composition obtained.
	Per cent.	Per cent.
Carbon	2.50	2.660
Manganese	1.50	1.640
Silicon	0.50	0 587
Sulphur	0.01	0 01
Phosphorus...	0.01	0.01

The tensile test of this alloy gave 22.41 tons ultimate stress. The turner reported that this alloy also machined like a very tough malleable iron. 150 heats gave the results shown in Table XX. They are also shown graphically in Fig. 2.

TABLE XX.

Length. Inches.	Diameter. Inch.	Volume. Cubic in.	Change. Per cent.	Weight. Grammes	Change. Per cent.	Heat No.
6.0040	0.9399	4.1663	—	504.09	—	—
5.9940	0 9396	4.1556	−0 27	503 43	−0.13	24
5.9961	0.9391	4.1517	−0.36	502.39	−0.34	50
5.9865	0.9396	4.1504	−0.39	500.87	−0.64	75
5.9890	0.9395	4.1522	−0 35	499.60	−0.89	100
5.9913	0 9401	4.1579	−0 21	499.36	−0.91	125
5.9937	0.9403	4.1614	−0.13	499 05	−1.00	150

This alloy contracted very slightly but steadily for 75 heats, the amount then being 0.39 per cent. Afterwards the contraction diminished also very slightly, and after 151 heats it was found to be 0.13 per cent.

So far as these conditions are concerned, therefore, it may be claimed as an alloy which does not grow at all after repeated heating, but on the contrary undergoes a slight shrinkage, which at no time amounted to 0.4 per cent.

Tensile Tests of Bars Subjected to 151 Heats.

In view of the rapid deterioration of the mechanical properties undergone by grey irons during growth, it was considered most important to test bars Nos. 1-4, after their prolonged and repeated heatings. They were accordingly machined to 0.564 of an inch, and broken in the testing machine with the results shown in Table XXI.

TABLE XXI.

Bar No.	Original Bars.		Bars after 150 heats.	
	Ultimate Stress.	Fracture.	Ultimate Stress.	Fracture.
	Tons per sq. in.		Tons per sq. in.	
1 ...	19.92	Platey.	17.00	Close dull grey, almost non-metallic.
2 ...	20.20	,,	21.92	Lighter grey, more metallic.
3 ...	22.0)	,,	*25.68	Lighter grey, more metallic.
4 ...	22.41	,,	*24.69	Very light grey, and most metallic.

* These figures would have been even higher had the bars not fractured in the screw-head.

The results are very important and remarkable. No. 1 shows a diminution in tenacity of 2.92 tons, but is still good. No. 2 shows an increase of 1.72 tons, while No. 3 shows an increase of no less than 3.68 tons, and, as explained at the foot of the table,

this must be regarded as a minimum increase, and lower than the probable figure. Most important of all, No. 4, the non-growing bar, shows a rise of 2.28 tons, which must also be regarded as a minimum figure. Its tenacity is thus markedly improved by treatment, which invariably causes a deterioration of that of the grey irons. From the practical standpoint, no result of higher utility could have been obtained.

The results of the tensile tests are given in Table XXII. Both temper and total carbon were estimated, thus enabling the percentage conversion of combined to free carbon to be calculated. The following conclusions can be drawn:—(1). There was only a slight burning off of carbon during the heats. (2). Manganese increased the stability of the carbide at 850 degrees to 900 degrees C. (3). The order of growth of the bars is the same as the order of magnitude of the temper carbon. There is clearly a relation between the two.

TABLE XXII.

Bar No.	Manganese per cent.	Original bars.	Bars after 151 heats.			
		Total carbon all combined.	Combined carbon.	Temper carbon.	Total carbon.	Percentage converted.
1	0.510	2.40	0.693	1.453	2.146	67.71
2	0.735	2.40	0.956	1.134	2.090	54.26
3	0.935	2.25	1.192	1.011	2.203	45.89
4	1.640	2.65	2.367	0.251	2.618	9.60

Freezing Point Determinations.

These were made in the case of alloys Nos. 3 and 4 because they have an important bearing on their cost of production. The alloys begin to freeze at 1,346 degrees C., depositing a silico-austenite, containing possibly manganese. The freezing interval continues down to 1,120 degrees C., the eutectic temperature, when the eutectic of silico-austenite and cementite solidifies. During the next 400 degrees to 430 degrees C., primary cementite, probably containing manganese, separates from the silico-austenite. Finally, at about 692 degrees to 718 degrees C., the latter inverts to a mixture of silico-ferrite and cementite, viz., silico-pearlite. This, of course, is the eutectoid inversion. Thus the final products are two:—(1). Primary cementite, most probably containing manganese in the form of a double carbide of iron and manganese; and (2) silico-pearlite.

TABLE XXIII.

Bar No.	Manganese. Per cent.	Growth per cent. after 151 heats.	Percentage of carbide decomposed after 151 heats.
1	0.510	+ 7.49	67.71
2	0.735	+ 6.06	54.26
3	0.935	+ 3.09	45.89
4	1.640	- 0.13	9.60

The retarding influence of manganese on growth, and the deposition of temper carbon from white irons, is well seen in Table XXIII.

Recommendations as to the Choice of Alloys of Negligible Growth.

The investigations described in the foregoing Paper, and in that by Professor Rugan and the author, have not resulted in the discovery of an alloy whose volume is absolutely unaltered after repeated heatings. Either there is growth or shrinkage. It may be very slight, but it is none the less there. For practical purposes, however, it will be assumed that a variation in volume of not more than 0.5 per cent. is permissible. The research was originally taken up to discover, if possible, an alloy suitable for annealing ovens, or, speaking more generally, for objects which are neither rapidly heated nor to a very high temperature, in which, therefore, it was thought that a considerable degree of brittleness was allowable.

In the discussion, however, the author's results were judged to a large extent from the point of view of their applicability to objects, such as ingot moulds, which have to stand the pouring into them of fluid steel at about 1,600 degrees to 1,700 degrees C. without cracking; that is an immensely severer test, not only as to absolute temperature and rapidity of heating, but also as to deterioration by reaction with the molten metal. This was a stress they were never intended to bear, but in this, the concluding paragraph of the Paper, the author's results, so far as they bear on them, will be discussed. The alloys experimented with in Part IV. may be regarded as semi-cast irons, from the point of view of their carbon percentage. They contain from about 2.25 to 2.5 per cent. of this element, with about 0.5 to 0.6 per cent. of silicon. The experiments have shown that, in order to obtain, on this basis, an alloy whose growth on repeated heating is negligible, about 1.5 per cent. of manganese must be present. Such an alloy melts at about 1,350 degrees C., which lies between the melting-points of mild steel and cast iron, though somewhat nearer the former. It is a tough material, "turning," as has been described, "like a very tough malleable iron." The melting-point is, of course, somewhat high, and this could be decidedly lowered by adding even larger amounts of phosphorus and sulphur than are usually present in commercial irons, without any danger of growth, but undoubtedly at the expense of toughness. The valuable practical property of this alloy is that repeated heating, at any rate up to 150 heats, substantially improves its tenacity, and probably its ductility also, for whereas its original tenacity was 22.41 tons per square inch, the final value was 24.69. This result is highly gratifying.

The slight deposition of temper carbon that takes place on repeated heating will certainly not make the material any more brittle. It certainly appears as if this alloy could be tried with advantage for annealing ovens, rolls, fire-bars, and the grids of muffle furnaces, whose growth is so annoying a characteristic, none of which are heated up very rapidly in ordinary use. Further, the author is of opinion that it could be used for ingot moulds in an ironfoundry without cracking, and without growing, but it is doubtful whether it could withstand molten steel. Taking all things into consideration, it looks as though the cheapest ingot mould for molten steel in the long run is one similar in composition to alloy I., itself a mild steel, or one containing even less carbon. The first cost is, of course, high, but it is much less likely to crack than the semi-cast iron, and its growth would probably be negligible. No doubt, a grey iron, containing plenty of graphite, would be less liable to crack, but the author knows of no treatment which could prevent its growth under these conditions.

Summary.

(1). Phosphorus tends to diminish growth. If 0.3 per cent. is present growth is lessened by about 3 per cent. Higher percentages tend to diminish growth still more.

(2). Sulphur is never present in commercial cast irons in sufficient quantity to have more than a small influence on growth, which is, however, in the direction of retardation.

(3). Manganese retards the rate of growth in all cases, and diminishes the absolute amount in the majority of cases.

(4). Dissolved gases have no influence on the growth

of an iron containing more than 3 per cent. of silicon; between 1.75 and 3.0 per cent. of this element they may cause a growth of from 1 to 2 per cent. Their influence is most potent when silicon does not exceed 1 per cent., and in such cases they may be responsible for a growth of at least 10 per cent.

The simplest and most rapid test for forming an opinion as to the growth that is liable to take place in any particular grey iron is to estimate the silicon, and then read off the approximate growth from the data as follows:—

Silicon per cent.	Approximate growth per cent.
1.00	15.0
1.25	18.5
1.50	21.5
1.75	24.5
2.00	27.0
2.25	29.0
2.50	31.0
2.75	32.5
3.00	34.0
3.25	35.5
3.50	37.0

(6). Alloys containing from 2.25 to 2.40 per cent. of carbon, 0.40 to 0.48 per cent. of silicon, and varying quantities of manganese, showed the following growths after 151 heats:—

Manganese per cent.	Growth per cent.
0.540	7.49
0 735	6.06
0.935	3.09

(7). An alloy, containing 2.66 per cent. of carbon, 0.587 per cent. of silicon, and 1.64 per cent. of manganese, showed no signs of growth after 150 heats, but, on the contrary, a slight contraction, namely, about 0.13 per cent.

(8). It is a tough material, and its mechanical properties were improved by this treatment.

(9). It begins to freeze at about 1,346 degrees C.

(10). It appears to be a suitable material for annealing ovens, rolls, fire-bars, and the grids of muffle furnaces, whose growth when in the form of grey irons is so objectionable a feature. Probably it could be used for ingot moulds in an ironfoundry without cracking.

(11). From the point of view of minimum growth and non-cracking, the most suitable material for ingot moulds into which molten steel is cast appears to be a very mild steel.

The Hard and Soft States in Metals.

In the course of the second annual May Lecture before the members of the Institute of Metals, Dr. G. T. Beilby, F.R.S. (a Member of Council of the Institute), said that the hardening effect of cold working on ductile metals, and the softening effect of reheating, must have been known to the earliest workers in metals. To the enquiring mind, the phenomena were sufficiently explained as being due to the "compacting" effect of hammering and the "opening up" effect of heat. The advent of more scientific methods of enquiry led to the exposure of this fallacy, and to the discovery of new points of difference in a metal in the two states. The discovery that the polishing of all substances, even of those so hard or brittle as antimony or calcspar, involves the transient liquefaction of a thin layer on the surface, led to the study of this subject from an entirely new point of view. In a pure ductile metal which has been slowly cooled from the molten state, the structure of the solid is completely crystalline, and the metal is in its softest condition. Any permanent deformation of the mass, whether by hammering, by rolling, or by wire drawing, hardens and stiffens it. The microscopic examination of the hardened metal shows that its original crystalline structure has been broken up and replaced by a new type of structure. If the hardened metal is raised to a sufficient temperature, the softness is completely restored and the crystalline structure is also restored. In the ductile metals the greatest degree of softness is always associated with well-developed crystallisation.

The composite character of the hardened structure, which in some cases resembles a bed of broken and distorted strata concreted or cemented together by a matrix, can only be explained by the presence of two constituents, namely, the broken-down remains of crystals, and an amorphous or glass-like form of the metal by which the mass is so firmly cemented together that it has become vastly more rigid and mechanically stable than the crystalline structure. This amorphous or vitreous form of the metal stands in the same relation to the crystalline form as glass does to the crystalline silicates of which it is composed or as the clear vitreous "barley sugar" does to the ordinary crystals of the breakfast table.

The pure ductile metals cannot be obtained in the vitreous state by cooling, because their molecules retain sufficient mobility to enable them to marshal themselves in crystalline formation for a range of about 800 degrees below the solidifying point. All the facts show, however, that when liquefaction is produced by mechanically-induced flow, the solidification is so rapid that the solid which results is in the vitreous condition.

The direct bearing of these researches on the obscure subject of molecular structure in solids was pointed out, and a "pulsation cell" hypothesis of the three states of matter was outlined.

Professor Quincke's "foam-cell" theory of solidification was referred to, and was applied to the explanation of certain observations made by Professor Carpenter some years ago.

Titanium in Iron Castings.

In a pamphlet dealing with their special titanium alloy Messrs. Geo. G. Blackwell, Sons & Company, Limited, of Liverpool, remark that the constant demand for iron castings of greater strength makes it incumbent on the iron founder to consider seriously every means of improving the quality of his goods. The scientific founder who abandons rule of thumb and antiquated methods, is bound to succeed and leave the other founder standing where he was. A suitable addition of titanium in a form manufactured specially for iron foundry work, is bound to improve the product. Titanium cleanses the iron, removes nitrogen and oxides, strengthens, toughens and removes brittleness and blowholes. Such castings machine better. Titanium in grey iron, malleable iron, machinery castings and chilled castings gives improved results. The castings show increased tensile strength, compressive strength, resistance to wear and greater durability. Chilled rolls, chilled car wheels, etc., show remarkable increase in wearing properties. Titanium iron contracts and expands less under heating and cooling, and ingot moulds cast from this iron last much longer. The alloy should be crushed fine and added to the ladle. The best results are obtained by pre-heating the crushed alloy before adding to ladle. The alloy should be stirred in thoroughly, and the quantity to use is from ¼ to ½ lb. per 100 lbs. of iron.

The Ruthenburg Electric Furnace.

The Ruthenburg electric furnace, which is depicted in the accompanying illustrations, is in many respects distinct from all other types. The furnace uses three-phase alternating current which revolves the bath, making for an even distribution of heat. The electrodes are immersed in the slag at a non-arcing voltage, the result being that the slag acts as a resister and becomes the centre of heat.

In designing this furnace the object has been to continue the good features of the various types which have previously been put forward, at the same time obviating the faults of these types. An idea of the general construction, as well as the exclusive features embodied in the furnace, may be gathered from the views herewith, and the sectional drawing, Fig. 4. The furnace may be described as belonging to the

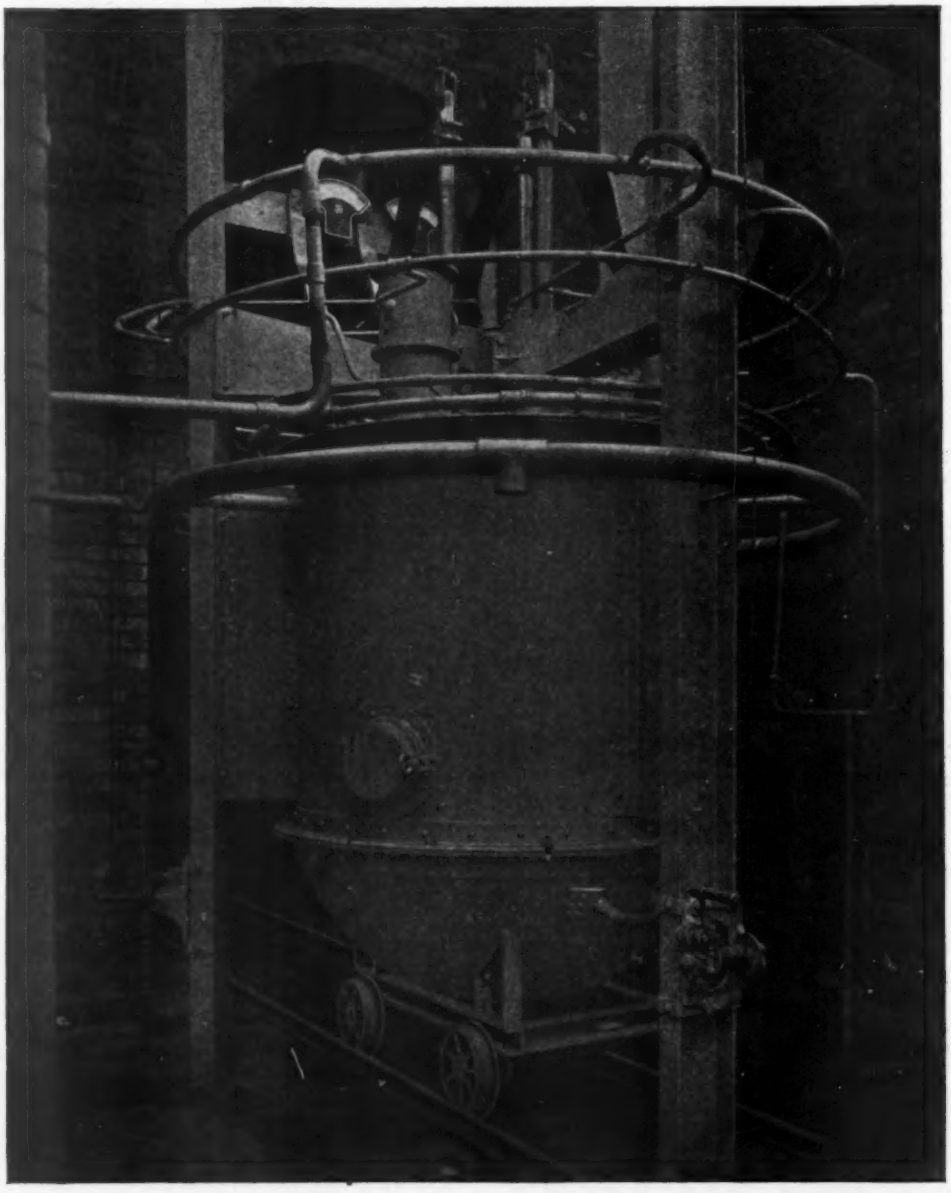


FIG. 1.—THE RUTHENBURG ELECTRIC FURNACE.

resistance type; that is, the heat is generated by the passage of a current of low tension through the bath, as opposed to the type in which heat is generated by a current of higher tension passing between electrodes and forming a true arc.

A special feature is the removable pouring hearth, the advantages of which are obvious. The hearth being removed and run out on its track is used as a ladle, thus obviating skulling, loss of heat, and consequent loss of efficiency. It will also be observed that by this method metals may be poured which would be extremely difficult to release by tapping. Other advantages claimed for this construction are the increase in accessibility, and the feasibility of keeping the furnace in continuous operation by the substitution of a spare hearth, when the running hearth requires re-lining or repair. The time required for lowering the hearth, pouring and replacing is negligible as compared to the time necessary for releasing the same amount of metal by tapping.

The electrodes are protected by water jackets extending to within a few inches of the bath, these jackets being lined with refractory material. The

FIG. 2.—REAR VIEW OF 8-IN. ELECTRODE RUTHENBURG FURNACE.

jackets serve to protect the electrodes from the wasteful action of the extremely hot gases. Unprotected electrodes, exposed to the actions of these gases, have a decided tendency to fritt away, this fritting action involving a serious waste of electrode material. The refractory jacket lining precludes any possibility of arcing between the electrode and the jacket wall, in the event of an electrode being broken.

We understand that a furnace embodying the above features, with slight alterations to suit individual needs, has been applied to the refining and alloying of steel, the production of steel direct from ore, the melting and refining of steel scrap, borings, drillings, punchings, etc., the production of ferro-manganese, ferro-chromium, ferro-vanadium, ferro-silicon, and spiegeleisen, the treatment of complex ores, carrying gold, silver, nickel, cobalt, zinc, copper, sulphur, lead, etc., the smelting of copper ores, and the melting and refining of non-ferrous alloys. The makers of the apparatus claim that in refining and alloying steels, the Ruthenburg resistance furnace is superior to furnaces of the induction type, as it avoids losses due to radiation, keeps the bath in circulation, and has a very high efficiency as to current consumption. Either acid or basic hearths may be used, and the cost of refractory upkeep is extremely low. Iron ores may be smelted in the furnace for the production of steel direct, furnaces for this purpose being fitted with the necessary appurtenances for introducing carbon monoxide for reduction purposes, while as regards the melting of scrap, inasmuch as in ordinary melting processes

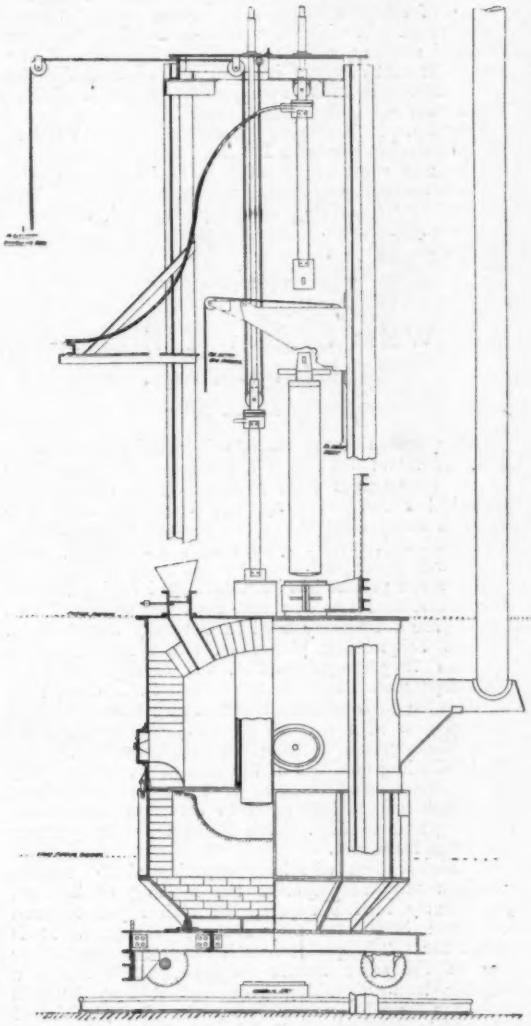


FIG. 3.—GENERAL ARRANGEMENT OF 12-IN. ELECTRODE RUTHENBURG FURNACE.

40 per cent. of any light steel scrap that may be fed into the furnace is burned and slagged, and consequently only 60 per cent. recovery made, it is patent that an electric resistance furnace is peculiarly suited for the work, as it makes possible a recovery of 100 per cent. in such melting work, with the expenditure of a minimum amount of energy.

Regarding power consumption, more particularly in regard to steel, the makers state that 1,000 kw.-hours covers the complete consumption of energy for melting and refining wrought-iron and steel scrap. A slag of

burnt lime and pure iron is used, and the scrap is largely tube billet borings, lathe turnings, planer clips and armature sheet punchings. The ingots are stated to be perfectly sound and particularly free from occluded gases. The power factor of the furnace is over 0.9, which is very high, and is remarkable for a furnace having as much iron in its construction as this type. Practically the only repair to refractories is in mending the hearth. There is no loss in roof at all, a single roof having been used for nearly three years. This is in strong contrast to some other furnaces used in melting steel, in which the roof repair is one of the main items of expense. The makers claim that, given current at 0s. 3d., which is a price obtainable from many central stations, a ton of steel may be produced at an inclusive cost of 30s. When it is considered that low-price scrap, *i.e.* tube swarf, turnings and borings, is used, this 30s. is more than offset by the low cost of the scrap. It is also to be remembered that 100 lbs. of clean scrap produces 100 lbs. of steel.

The sole right to manufacture Ruthenburg electro-metallurgical apparatus has been granted to the Brush Electrical Engineering Company, Limited, of London and Loughborough.

The Weiss System of Briquetting Metal Borings.

The question of the use of briquetted iron and non-ferrous metal borings for foundry work has been much discussed of late, particularly in the German technical Press. We append, therefore, some particulars concerning the Weiss system of briquetting this material, which system has, we believe, been fairly widely adopted.

The Weiss process has been developed during the last few years, and the iron and steel briquettes of this system are extensively used in Germany and Austria. In the briquetting plants on this system installed by the Ziegelungs-Syndikat, the borings are carefully separated magnetically from dirt and dust, then mixed with limewater and deoxidising material (steel borings also with carbonising materials) and pressed under high pressure. The resulting briquettes, owing to the binding qualities of the limewater, become very hard after a short time, so that they will withstand the rough usuage incidental to carriage, and during charging and melting. The limewater also protects the metal from rust.

To foundrymen who have experienced the trouble which usually accompanies the melting of borings, particularly in the cupola, the claims put forward for these briquettes may seem extravagant. It is stated that—"Briquette iron is softer than any other iron of the same tensile strength, which means a tougher iron. Speaking generally, it may be said that iron from briquetted borings has the qualities of charcoal iron, or iron melted in the air-furnace, owing to the refining process which takes place during the melting of the briquettes. Thousands of locomotive and steam-engine cylinders and other complicated castings, subject to severe specifications, have been poured from iron containing briquetted borings and no difficulties have been experienced in complying with the specifications. In mixtures to avoid sponginess—which is liable to occur on the surface of castings having great variations in their sectional dimensions, as gear wheels with cut teeth—briquettes of iron or steel borings have always been successfully employed."

It is further claimed that the Weiss process allows the use of a very large proportion of briquettes in the charge, especially in the case of steel briquettes, which, without carbonising materials, can hardly be melted in amounts greater than 20 per cent. of the charge. At some "baby Bessemer" plants, we are informed, up to 80 per cent. of steel briquettes are being used, together with an iron high in silicon; or 40 per cent. of briquettes, 40 of steel scrap and 20 of high-silicon pig-iron. These mixtures are said to give a very fluid metal. Some care has to be taken as to the proper mixture regarding silicon and phosphorus contents, and this has to be tested and ascertained by the founders themselves. The selling price of turnings briquetted by the Weiss process is given as being in Germany about 1s. 8d. per 200 lbs. (18s. 8d. per ton), for unalloyed briquettes.

Brass and bronze briquettes produced by the Weiss process have an addition of lime which is combined at a high temperature and under high pressure with carbonic acid, which in melting gives off CO_2. This gas excludes the air from the crucible and prevents oxidation, while at the same time the additions flux the metal. We are informed that briquettes without any addition of new metal are being melted and poured direct, the resulting castings proving quite satisfactory. In the ordinary way metal melted from borings, either in the air furnaces or in the crucible, is of interior quality, and has to be poured into ingots and only used in small quantities with new metal. Some founders melt their borings by charging them in small quantities together with new metal; but this practice is liable to result in heavy losses of metal.

The presses needed for the Weiss process are capable of exerting a pressure up to 500 tons, and produce about 40 tons of briquettes per 10 hours. Only large companies can, therefore, run such a plant for their own use. Smaller works have their borings briquetted at some general plant which caters for the small founder.

Sulphite Lye for Core-Making.

The left bank of the River Elbe, from Pirna down for some distance, is lined with wood-pulp mills, which grind and boil the pine from the up-stream Saxon and Bohemian forests. As a waste product there was formerly a most unpleasant mixture of sulphite and woody fibre. This is now used most successfully in core-making for foundry work. The lye is of brown colour, readily soluble in water, and is used in the foundries at a density of about 35 deg. Beoumé. It contains in the form:—Water and substances volatile at 110 deg. C., 40.1 per cent.; ash, 13.3 per cent.; combustible substances (organic), 46.6 per cent. Of these components, none are injurious to the health of the foundrymen or the quality of the castings. The lye is mixed with water and the dilute solution sprinkled over the sand. The necessary proportions vary with the conditions, but in general one may say that for 1,000 lbs. of sand 5 lbs. of the concentrated lye are taken and mixed with sufficient water to give the sand the necessary dampness. The cores are firm and hard, dry rapidly and thoroughly, are very porous, and require no venting. The material may be used with ordinary building sand, or with old sand from the cleaning floor. The cores are especially smooth, and where there are fine ribs, they are sharp and unbroken. In cleaning the castings the cores fall out as a dry powder; they do not need to be blackened, nor are core irons necessary. They neither boil nor fall apart when the metal is poured, and some founders prefer the lye to molasses and other mixtures.

Gas Cavities, Shot, and Chilled Iron, in Iron Castings.*

By Thos. D. West.

About eight months ago, at the request of the writer, the foundry journals and iron-trade Papers of this country and Europe kindly published an article soliciting samples of iron castings showing globules in gas cavities, solidly encased shot iron, hard streaks or spots in castings, and white areas inside of grey or soft iron. Those forwarding such samples were requested to give full information as to mixture, melting, shape of casting, moulding, heat of pouring, etc.

Losses by defects as stated in the subject title above have caused many firms much worry and trouble before they could be made to disappear. The greatest annoyance, however, would arise from the fact that the trouble would be abated, but its origin could not be traced, and hence intelligently guarded against thereafter.

Experiences contributed by certain firms sufficed to counteract the theory often advanced that small chilled or hard bodies going into the cupola may cause hard shot, streaks, or spots in the iron castings.

Shot Causing Hard Spots and Blow Holes in Iron Castings.

A Massachusetts firm sent a sample of defective casting showing a small, hard button or "shot" loosely embedded within the nowel or down cast face of its surface. The peculiarity of this sample lies in there being a vertical, small blow hole leading directly from the top of the hard shot seen at A to the cope surface,

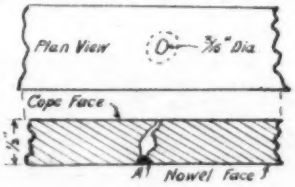


FIG. 1.

FIG. 3.

so that upon removing the shot one could see clear through the body of the casting, this being about a half inch thick. It gives evidence of the hard shot or foreign material while lying near the bottom surface of the casting emitting a gas which went upward through the molten metal to the sand surface of the cope, but not sufficiently fast to prevent the creation of the small, vertical blow hole shown. In order to clearly observe the full surface and character of this blow hole the sample was fractured and the hole is sketched closely, as seen in Fig. 1.

Several samples of soft iron castings have been received containing solidly encased or cemented small bodies of strictly white iron. The term "cemented" is used here, as the spots, or white bodies, are in no wise loose in the casting. They form a part of it, showing differences in colour of white and grey, but are as solidly united as this is possible for any two plastic materials, each of a different grade and colour, to be so. Not only is this defect obtained in a shot or spot form by founders, but also in streaks and bodies of considerable area. Defects of these characteristics are most generally found at the upper cast body, face or edge of castings.

* Presented before the American Foundrymens' Convention, Pittsburg, May, 1911.

Experiments with Shot Iron placed in Moulds.

Some shot iron was received by the writer which had been taken from a cupola spout after the bottom was dropped, on the supposition that it could cause blow holes if introduced into the mould. The experiments showed, aside from the "blow" question, that unless shot iron was up to a very high red heat, or near the fusing point (as is possible in many cases when they are formed in pouring a mould), that casting metal under three-eighths inch in thickness would have little effect in melting them, unless they might rise to be embodied in nearly the middle body of the casting, especially if the shot are roughly over one-eighth inch in diameter. The shot which the writer used in the above experiments were placed on the bottom face of the mould at the end farthest from the pouring gate, so that the wash of the metal would not be so liable to disturb them. An examination of the castings when cold showed the shot in their original position and not united to the body of the castings, when fractured along a line in their position.

Causes for the Creation of Shot Iron in Castings.

The logical reasoning regarding the creation of the small, hard particles or metal shot found in some castings is that they become suddenly separated from the general mass of metal during the pouring of a mould.

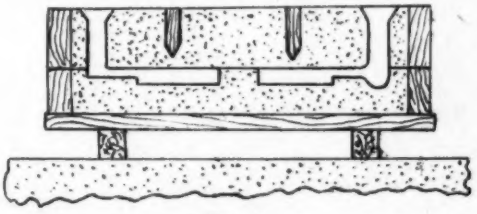


FIG. 2.

When thus separated they solidify so quickly that not sufficient time is given for the carbon to be separated out as graphite Hence the shot does not have the softness of the rest of the casting which had more time to cool.

The longer the distance a shot is sent through the air before it lodges and the cooler the air it passes through, the harder the shot. Affecting this also is the degree of dampness of the spot upon which the shot may lodge. Where shot is caught and covered by incoming metal before it has time to become cooled below a red heat, the chances for their being hard and discoverable in a casting are not of course nearly as great as when they can become of a dark colour before being encased by the liquid metal.

Particles of iron or shot may be formed during the falling of the metal from the ladle's pouring lip by striking the sides of a pouring basin or gate; again, by falling upon a flat bottom inlet gate, as in Fig. 2; or when the metal reaching the mould strikes some obstruction fronting the gates to splatter the metal. In ordinary plain work there is probably no feature so harmful in causing a splattering as having flat gate bottoms, as shown. The bottom of all pouring gates should have more or less of a well (see Fig. 2), as

by this information, if there is hesitation for a moment or so when starting to pour, the first droppings from the ladle fall into the well shown, to stay there in a liquid bulk and not be spattered to create shot.

In starting to pour the majority of moulds, especially those of a light work and stove plate character, there should be no momentary stoppage after starting, but from the instant the falling metal first strikes the bottom of a gate, there should be a steady and unbroken stream to rapidly fill the pouring, and kept so until the mould is filled. This applies to the flat top pouring gates generally used for stove plate, etc., as well as those of the joint character, shown in Fig. 2.

Dampness and Sudden Cooling.

The too free use of a swab or sponge in wetting the joint of a mould, before drawing a pattern, or after this is done in finishing a mould, can easily harden or chill the metal parts of a casting formed where this excessive dampness existed. Other causes are too damp a mixture of sand, hard ramming or insufficient venting. Metal striking these damp sections will often bubble and splatter to a greater or less degree. This action can in some cases create suddenly chilled shot that will be carried to other sections of a mould to become encased in liquid metal and thereby give the white iron or chilled shot found in some castings.

The above is not intended to account for all the white iron, chilled shot, streaks, etc., found in castings, especially those of a light work and stove plate character. However, a solution of the phenomenon relating to "inside chill," i.e., a white or chilled centre to a grey or soft casting, should greatly help founders to prevent some of these annoying and costly experiences.

Creation of Globules in Gas Cavities and Blow Holes.

The next defect to be considered is that of globules in gas cavities and blow holes, as in Fig. 3. These defects can be due to two conditions but emanating from one cause, and that is the creation of excessive gases or steam that cannot find its liberation from imprisonment within a body of solidifying metal. They are found chiefly in the upper body or cast end of castings.

Excessive gas, causing blow holes or cavities, may come directly from the metal or wholly from defects in moulding or pouring. Those due to the iron may be caused by oxides of iron or manganese reacting on the iron's carbon, the former producing carbon mon-oxide gas, or on liberated graphite creating kish (although of the latter there is very little in remelted iron, it being chiefly found in direct metal at blast furnaces); also indirectly through sulphur, by reason of the formation of sulphide of manganese, and again by a foreign body like that possibly created by the mixture of iron oxide and dross (the latter may contain some kish in connection with the dirt generally coming from clays of the cupola tap hole and spout, and other sources) forming a slag on the top of a ladle's metal that could pass in small bodies into a mould at the starting of pouring, or later on before a mould is filled, through defective skimming. Thereby often large as well as small blow holes or gas cavities are formed. As a side issue it can be said that a ladle's surface dross can easily cause dirt holes, pin holes, and a dirty surface to the finish parts as well as the rough surface of castings when skimming is at fault in pouring a casting.

Gas cavities and blow holes due directly to defects in moulding and pouring are often due to not having properly tempered sand, regulated degrees of hardness in ramming, efficient means of venting, and correct methods of finishing cores and moulds, combined with experience in gating and pouring.

Globules when suspended from the roof of a cavity, as at B, Fig. 3, are evidence that the cavity is probably due to something being wrong in the method or manner of making, gating or pouring the mould. The mould's gases or steam creating these cavities may be originated during the filling of the mould, and again may not until some time after the mould has been filled, or before the main bulk of its metal has solidified. Imprisoned gases or steam, due to defects in moulding, form a cavity into which the outer body of liquid metal may with favourable conditions ooze to form loose shot or suspended globules, as seen at B, Fig. 3. The actions of globules or any liquid, also any special elements, finding access to such cavities may continue at intervals for a short time after a gas cavity has been formed, or as long as the body of metal surrounding the cavity remains in a fairly liquid state. The larger the cavity the greater the chances of this action. Globules finding access to a gas cavity at its upper end, as in Fig. 3, may be credited to the law of specific gravity and also to the condition that heat rises and that the upper body of metal is as a rule more fluid than the lower.

Cavities created solely through conditions of the metal, or its constituents, or again strictly by splashes of oxidised bodies of metal, or foreign solid matter should more generally present an unbroken, smooth bright surface. The metal, or confined oxidized shot conditions that start these cavities are such as can in some cases continue the creation of gases to make a higher internal pressure, to prevent globules, liquid metal, etc., entering their space, than exists where gases become imprisoned from a source that cannot add to their volume, or increase their pressure, as would more generally be the case if created wholly by defective moulding.

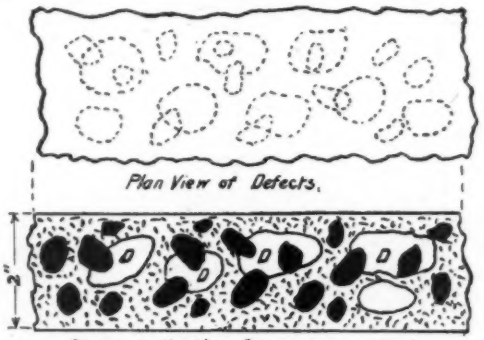


FIG. 4.

A casting may possess gas cavities that will be due to causes inherent in both the mould and the metal. This, for example, could occur through a mould bubbling or boiling its metal sufficiently to throw up small bodies or buttons of metal that would fall back oxidized into rising metal in the mould, and these bodies, buttons or shot could, by reason of their oxidization and probable gathering of dross, create a gas to cause cavities that would be companions to those created solely by the mould's steam or confined gases imprisoned in the metal. (See Fig. 4.)

I have little faith in sulphur or phosphorus forming blow holes in grey iron castings. Where mixtures are of a hard or chilling iron, I more seriously consider the sulphur and phosphorus excuses for blow holes or gas cavities, etc.

Investigations by Mr. P. Munnoch.

Among the letters that have come to my hands for consideration of this subject is one from Mr. P. Munnoch, of the British Foundrymen's Association, and as it presents some excellent information obtained by hard research work I take much pleasure in presenting the same as follows:—

"The chief peculiarity noticed in connection with shot is that they usually occur in the upper portion or near the upper surface of a casting. Generally they are small in size and almost round. In some cases they entirely fill the cavity in which they are formed, in others they only partially fill the cavity. When fractured the appearance varies from grey to white. When machining castings the tool will usually jump over the white variety as this is extremely hard."

"The analysis given in Table I. shows the composition of shot and buttons and also composition of castings from which these were taken. They are arranged according to phosphorus content. Most of these analyses are from specimens obtained from large castings.

TABLE I.—*Analysis of Metal, Shot and Buttons from Castings.*

Fracture.	1 White.	2 White.	3 Mottled.	4 Mottled.	5 Mottled.	6 Mottled.	7 Mottled.	8 Gray.	9 Gray.	Gray.
G.C.	—	.33	1.16	—	—	1 68	2.02	2.44	—	2.45
C.C.	2·20	2.00	1.25	1.00	—	1.05	.75	.76	—	.85
Si.	.70	.84	.93	.60	.86	.93	.98	1.26	1.14	1.321
Mn.	.63	.59	.48	.63	—	.36	.50	.45	—	.43
P.	5.68	5.45	4.88	4.84	4·64	3.80	3.20	1.92	1 80	1.70
S.	—	.016	.031	—	—	.021	.037	.046	—	.031
Casting ...		B	B	D	E	C	F	F	E	A

TABLE II.—*Analysis of Castings from which Shot were Taken.*

	A	B	C	D	E	F
G.C.	2.74	2.80	2.90	3.25	2.80	2.85
C.C.	.02	.50	.40	.05	.60	.60
Si.	1.63	1.72	1.70	1.77	1.95	1.65
Mn.	.51	.49	.45	.44	.48	.49
P.	.88	.83	.89	1.23	.95	.84
S.	091	.118	.114	.107	.105	.119

All the above analyses were cylinder heads except E, which was a pedestal.

In some cases several ounces in weight were obtained, the holes from which they were taken being very much larger than the buttons of metal found in them."

"My first experience was with grey shot enclosed in small castings. In some cases these were apparently shot of metal splashed into the mould at the commencement of pouring, and then after oxidizing on the surface became enclosed in the liquid metal. Afterwards I came across some peculiar castings, from which I obtained large buttons and pieces sufficient to make complete analysis from. The analysis showed that these could not be merely splashes of the original metal, but must have been liquidated from the interior of the casting after the greater part of the metal had solidified. The analysis of the buttons appeared very similar to that of the metal drops squeezed out of phosphoric pig iron after the metal had solidified, by submitting it to hydraulic pressure, in some early experiments by Mr. J. E. Stead. I therefore submitted some of the specimens and analysis to Mr. Stead, and his opinion was that blow holes were first formed, and these afterward became filled with the highly phosphoric liquate."

Obtaining Large Shot or Buttons from Gas Cavities.

"Some large cylinder heads for blowing-engines supplied interesting specimens, pieces several ounces in weight being obtained. In some cases pieces or buttons of different compositions were obtained from different parts of the same casting and pieces of different compositions were found in the same cavity. The castings weighed about ten tons, the thickness varied considerably and the moulds were largely built up of cores, some of which were difficult to vent satisfactorily. The castings were square, with a circular web and flange running around the top, and the holes were formed in the top flange. The holes were only revealed after machining and after removing a good thickness of metal. The holes were large and the interior in most cases was bright, but in one or two cases small masses of oxide were found. The upper surface was smooth, with rounded projecting crystals, indicating the rising of gases after a considerable thickness of metal at the top of the mould had set. The lower part of the cavities showed signs of shrinkage in places, but the bottom was usually covered by the liquidated masses."

"The buttons themselves were smooth, with a bright, mirror-like surface, which they retained after several years' exposure to the acid fumes of the laboratory. The buttons were rounded at the edges, and therefore could not have been very fluid when run. In some cases small shot were partly enclosed by larger masses, and this, together with the difference in composition, showed that the liquidated metal had not all entered the cavity at the same time, but at different periods of solidification. In some cases the small shot present appeared to have been squeezed into the cavity. The gray shot were similar to the casting in fracture, the mottled shot not unlike ordinary mottled iron, the white was much like white iron, but the outside part showed a crystalline appearance in the form of long crystals, interlaced and partly covered with a thin layer of graphite in some cases. There was evidently a contraction of the outer shell or expansion in the interior set up after the metal was almost solidified and the pressure set up caused the still liquid portion to be squeezed from between interstices of the already formed crystals, into the cavity formed previously."

High Phosphorus Shot.

"For comparison, analysis of liquid which is squeezed out of low phosphorus forge pig-iron is given in Table III. In this case the exterior is solid and the contraction

TABLE III.—*Forge Pig-Iron (Low in Phosphorus) With Portion Squeezed Out.*

	(Pig-Iron.) per cent.	(Liquate). per cent.
G.C.	3.06	3.30
C.C.	.78	.58
Si.	1.23	1.30
Mn.	.78	.82
P.	.043	.016
S.	.091	.034

of the shell or expansion in the interior forces out some of the still liquid metal from the interior. In the case of the castings it is not the still liquid metal which is forced into the cavities, but the phosphorus-enriched liquid remaining in the spaces between the crystals, at the time when the pressure is set up. The liquid is gradually enriched in phosphorus until the phosphide entectic containing 6.7 per cent. phosphorus, 2.0 per cent. carbon and 91.3 per cent. iron is reached, and the amount of phosphorus in these buttons is an indication of the period during solidification at which they were formed. The shot in which the phosphorus is very little different to that of the castings may in some cases be due to splashes of metal entering the mould at the commencement of pouring, becoming coated with oxide and becoming simply encased in the following molten metal. Or shot may be formed by a compressive action similar to that illustrated in the case of forge pig-iron in which a portion of the still liquid metal in the interior of the casting is squeezed into a previously formed hole. In this case the composition would be much the same as that of the casting in which it is found.

Effect of Oxidising Condition on Metal and Shot.

"Generally the formation of shot holes and shot are most noted in iron which has been subjected to oxidising conditions during melting. Instances of this may be seen when the first metal from the cupola runs cold, particularly when the softer variety of iron is being

melted. If this is caught in a ladle and allowed to solidify it often presents the appearance of a spongy mass full of shot, the holes and shot being coated with oxide and graphite. Should some of this be left in the bottom of the ladle and some hot fluid poured over it, a boiling action follows, and if poured into moulds the castings produced contain many holes of the shot hole type. Holes of this kind may be bright or tinted inside, they usually contain specks or flakes of graphite and often contain particles of oxide in the lower part."

A Review of Mr. Munnoch's Research Work.

The above description, analyses, etc., of Mr. Munnoch's researches are exceedingly valuable. The writer offers the following comments on causes and remedies for the defects cited. The first item he would call attention to is Mr. Munnoch's statement of "some castings weighing about ten tons, with thicknesses varying considerably, and the moulds were largely built up of cores, some of which were difficult to vent satisfactorily." If I were asked what was the cause of the buttons, shot, gas cavities or blow holes in the castings cited by Mr. Munnoch I would, to make a brief reply, say: "The moulds." The character of the metal used had practically nothing to do with their creation. In other words, had the moulds forming these castings been poured with right temperature metal, through well-constructed skimming gates, without the occurrence of a flurry, bubble or boil, as the mould was filling up, or afterwards in the metal solidifying and being brought to a solid state by proper feeding, I venture to say that in all the castings not a single gas cavity or button of metal would have been found.

Mr. Munnoch shows that he obtained some very large specimens of shot or buttons, such as a bubbling or blowing mould could easily create. These buttons or shot having been oxidised or covered more or less with a dross collectible in their upward and downward flight, would naturally create some gas cavities when liquid metal surround them. Another point that should not be lost sight of is the great chances there are for the creation of blow holes entirely free of either buttons or shot in castings in which the metal had bubbled or "blown" when they were being poured and cooled to a solid state.

A close study of the gas cavities cited by Mr. Munnoch shows that there were two kinds. Some of these were formed by the gas created from an embedded button or shot. Others by the sole effect of gases or steam created by a mould or its cores endeavouring to escape from imprisonment, but being caught formed cavities into which were forced particles of the surrounding metal to form buttons or shot that might hang to their roofs or be loose in the cavities.

Buttons, Shot and Gas Cavities created by Methods of Gating.

The writer's receipt of letters and samples brought some replies that while not strictly in the line sought for, bordered upon them so closely they are valuable enough to be considered herewith. In one special case a large retort casting was rejected on account of the existence of many cavities and large buttons of metal mixed with masses of dross in a certain location of the cope section of his casting. The sample forwarded is seen at Fig. 4. I came to the conclusion that the defects were wholly due to the method of gating used. The mould was of green sand, and the metal rushing into it cut against some green sand fronting the gate for fully thirty seconds or more before it reached a level of the gate, so as to have metal in front of it to retard its cutting action. The inflow of the metal at the gate would on directly striking the bare face of the mould splatter in all four directions. The separated particles would fall back in partly solidified small bodies to often lodge on the top of dross created by the cutting action of the mould's inlet gate. As the metal rose slowly in the mould it lifted the accumulated bodies of mixed dross and solidified buttons of metal, carrying it all upward until striking a horizontal plane that imprisoned it to await a complete filling of the mould and solidification of the metal in it.

As regard the effect of dull metal, one correspondent recalls once having made ten sets of milling machines, the V-slides of which required to be perfectly free of blow holes, and clean when finished. After the castings had been on the planer, however, all showed shot iron in the top and cope V's. He decided that the shot was formed by the air in the mould and while the metal was travelling over the body of the cores; also that the shots were carried up into the top V's and the metal was not hot enough to re-melt the shot. The job was shifted to where a ladle could be swung right from the cupola to quickly pour the castings, and never another casting was lost because of shot iron.

Creation and Effects of Oxides and Gases in Iron.

Light work suffers, as a rule, from the oxidising conditions of melting and handling metal more than heavy work, causing light work founders to often have much trouble with hard spots, hard streaks and pin holes in their casting, shot iron in gas cavities being little in evidence with them.

The action of oxides of iron in liquid metal is a good deal like that of excessive sulphur, it reduces fluidity, causing metal to be sluggish and scummy. Melting iron dull oxidises it more than melting it hot. The higher temperature protects the metal better from being oxidised by reason of its dropping more quickly from the cupola's melting point through the fuel to its bottom bath and also by reason of the manganese and silicon in a mixture being brought to a higher fluidity to thereby the better assist the creation of a fluid slag for floating over a metal surface in a cupola's bottom to the more annul the direct oxidising effect of the blast.

Anyone giving much study to the various defects treated by this paper cannot but be greatly impressed with the importance of melting iron so it will come down as "hot" and fluid as practical, as an agent to help prevent many of the defects cited herein.

"Inside Chill" or White Iron Inside of Gray or Soft Iron.

The occurrence of "inside chill," so called by Mr. Walter H. Wiard, chemist of a large foundry firm in Illinois, who wrote me on this subject, is so seldom as to be never seen in a life's experience of a great many foundrymen. In the case in question the inside chill extended throughout the entire casting, and the demarcation from the soft iron was very sharp and distinct. Explanation for the "inside chill" has been published, but as far as I can remember did not receive my approval and led me to believe that some experiments to actually produce such results at will were necessary before anyone could feel satisfied with a solution of this problem. This the writer hopes to take up in the near future, and as an aid to this end he kindly solicits the experience and views of any that might think they could throw any light on this subject, as well as any of the other points treated by this paper.

Coke and the Foundry.

By Richard Moldenke.

A very instructive pamphlet on "The Coke Industry of the United States as Related to the Foundry," by Dr. Richard Moldenke, has been issued as a bulletin by the United States Bureau of Mines. The following are extracts:—

Charging Methods.

In the early times, when but little was known of the rationale of the process, it was found that when a good bed of either anthracite coal or, later, coke was put in the bottom of the cupola and the top of this bed was a considerable height above the tuyeres, so that the first metal charged was at or above the hottest part of the fire when the blast was on, the metal would melt and could be tapped out and poured into castings. It was only necessary to keep on charging metal and fuel together into this fire, but in such proportion that the melting would proceed steadily at the rate shown by experience to be proper for the cupola.

All that later practice did was to stop the indiscriminate manner of charging, and to separate metal and fuel into layers, so that the action would take place with some regularity and the mixture could be changed for different classes of work, and so that the metals could be caught with some degree of certainty during the melt. In view of the work of our early foundrymen it is a question whether this change in practice has brought about a real improvement in the quality of the castings. Aside from the achievements of foundry metallurgy in the light of our present knowledge, it may be seriously questioned whether there is much truth in the general complaint of foundrymen that pig-iron has deteriorated in the last few decades. Pig-iron men hold that pig-iron has improved and not deteriorated, and certainly modern blast-furnace practice is vastly improved, at least as to regularity in product. It would seem rather that the foundryman does not get as good results as formerly—that is, the foundryman who has no use for or does not know about the advantages of chemistry—because he cannot use the pig-iron as he formerly did, judging it by fracture. With the changes in blast-furnace casting practice the appearance of the fracture is no longer even a reasonably reliable guide.

Fortunately the introduction of chemistry, or rather metallurgy, into the foundry industry has done wonders, giving us the means to control our mixtures and start the process right, whatever we do to spoil it afterwards. Hence, also, has developed the tendency in this country to test the product not by cutting pieces out of castings, but by pouring test bars under conditions that give the metal as melted and poured into the castings the freest and best chance to show its qualities.

Uncertainties of Cupola Melting.

It is gradually coming to be recognised that the metal charged, be it ever so good, may be affected by a number of conditions during the melting and may turn out either as a creditable product or as a very inferior one. This is not to be wondered at. Melting depends upon the transmission of heat from the fuel to the metal at such a rate and in such degree that the solid mass of iron becomes liquid.

The rate at which chemical changes proceed in the cupola, the intensity of the reactions, and the consequent need of keeping conditions just right throughout a heat are shown by the fact that under ordinary conditions it takes only one-fortieth of a second for a molecule of the oxygen in the air of the blast to pass from a tuyere through the incandescent bed and into that part of the charge too cold for chemical reactions. This brief interval is all the time the oxygen has to combine with the carbon of the coke, and (under certain conditions) with some of the manganese, silicon, or carbon of the metal charged, or with some of the iron itself.

Thus the management of foundry melting, whether in the cupola, air furnace, or open hearth, becomes a continuous struggle to get the valuable result of melting while avoiding the deleterious effect (as shown by defective castings) of oxidation of the metal. It is no wonder, then, that there are still a few foundrymen in remote parts of the world who cling to the ancient but admirable crucible process, in which fuel and metal are not in contact. This process minimises the harmful effects of oxidation. Commercial reasons have practically eliminated the crucible process for plain cast-iron, so those foundrymen who want the highest grade of work select the air furnace, or hearth furnace, as it is often called, or perhaps the open-hearth furnace with regeneration of air and gas as fuel. In each of these processes the metal is in contact, not with the fuel, but only with the gases. Therefore, if the processes are carried on properly, there is a smaller chance for oxidation of the iron than in the cupola; moreover, the metal as it rolls down in little drops is not impinged upon by a current of gases containing abundant free oxygen, as it is in the cupola.

These statements do not mean that excellent metal cannot be made by the cupola process—metal that will prove just as good under test as air-furnace metal of like composition—but the chances are not in favour of such success; and for the highest grade of product, especially if safety of life and limb may depend on it, such chances should really not be taken.

Adjustment of Practice to Fuel.

Normal coke has 50 per cent. cell space and has, pound for pound, practically double the volume of anthracite. Hence during the melt the downward movement of the metal within the range of the melting zone must be twice as fast when coke is used as it is with anthracite. Therefore the difference between the first of the metal to melt and the last, with respect to the influences to which they have been exposed, is greater for a bed of coke as compared with a bed of anthracite of like weight. That is, the first metal to melt is likely to be the same on either the coke bed or the bed of anthracite, but the last metal, especially if the charge is very heavy, melts much lower down in the coke-charged cupola, and is necessarily subjected to a greater oxidizing influences, because the blast low down in the cupola contains more free oxygen. When anthracite is used the part of the bed where the melting is actually done varies least in position.

A study of the downward movement of the metal, as just stated, is important, as it suggests the way to make use, in regular casting practice, of practically every variety worthy of the name of foundry coke. Anthracite and coke, being practically identical in composition—that is, containing the same percentage of ash, fixed carbon, sulphur, etc.—differ radically only in physical structure. Thus, if the cell space of a coke is 50 per cent., as mentioned above, the coke has twice the volume of an equal weight of anthracite. Now, not all cokes have the same cell space, and, moreover, cokes differ in percentage of ash, etc. Hence a given weight of coke varies greatly in volume, and consequently the behaviour of charges of iron melted with it also varies. The foundryman when changing his brand of coke makes the mistake of believing that the new kind ought to be

handled in the same way as the old. It may be possible to do so if the two cokes have the same characteristics, but if they had not the foundryman is certain to get differences in results, which he usually ascribes to sulphur, high volatile matter, black ends, and what not. His coke dealer then hears from him. This difficulty is so marked that even when the same brand of coke is bought the year round and trouble results. investigation of the consignments often reveals substitution of coke from different companies located in the same general region. Blast-furnaces have this difficulty to contend with more particularly. It is therefore highly important that the foundryman get his coke from the same ovens and the same coal mines—in fact, have it as nearly the same as it can possibly be made; if a change is desirable or necessary he should be informed, so that he can adjust his work to the changed conditions.

In this respect the retort-oven coke has a great advantage. After the coals have been contracted for and the proper mixture has been established, the result will continue to be even as long as the coking process is carried out uniformly. Another advantage of retort-oven coke is the size and shape of the lumps. A retort oven is narrow, and the coking of a charge proceeds from the walls toward the middle; the result is a mass of coke that, when quenched, breaks into short, thick pieces. The absence of thin fingers is decidedly noticeable. In comparison, the lumps of standard grades of beehive-oven coke are generally longer and thinner. The size of the lumps of fuel in a cupola charge has much to do with the progress of the heat, and the absence of thin fingers accounts in a measure for the remarkable success of retort-oven coke when it was first used in foundries. Charges of coke having lumps that are uniform in shape and size give results similar to those obtained by using anthracite, which is marketed in screened sizes, because the uniform sizing of the fuel permits an even and regular penetration of the bed by the blast.

In order to adjust the process to the varying character of the coke used for melting in the cupola, it is necessary not only to change the melting conditions, for instance, by using a milder or stronger blast according as the coke is light or heavy, but also to change the relative weight of the metal and coke charges on the bed. A foundryman using heavy charges, though he may not know why, avoids coke with a large percentage of volatile matter. Such coke is necessarily underburned and light and ignites rapidly, spreading the melting through too large a volume. Very light charges will obviate much of this trouble, as the bed of coke will be kept more nearly uniform in height, and the melting will be done at the proper point. A coke in which the volatile matter is too high is virtually a gas coke and is too troublesome for use in the foundry, at least for cupola melting. It will serve well enough for all the other purposes.

Before the question of charging is taken up it will be of interest to review the original tests made by the United States Geological Survey at St. Louis, in the Exposition foundry, where a collection of cokes was tested under identical conditions of melting.

Coke Tests by the Geological Survey at St. Louis.

The cokes above mentioned were made under the direction of A. W. Belden, of the United States Geological Survey, and the melting tests themselves were made under the direction of the writer, assisted by Mr. Belden as executive. By being present at nearly every test, the writer was able carefully to gauge the behaviour of the several cokes and to determine their merits for the foundry. The cokes were naturally selected for their probable fitness for foundry purposes; that is, those having excessive sulphur and ash were barred.

In all about 190 tests were made. Three thousand pounds of metal were melted in each test. To have uniform conditions in the coke bed for each test and at the same time to suit the average coke made, the height of the bed above the tuyeres was fixed at 14 inches as the standard, and this height was kept for every test. The upper tuyeres of the cupola were not used. A melting ratio of 7 to 1 was adopted, as the diameter of the cupola was small. The coke for the bed was weighed and put in up to the proper point, as measured by a weighted wire. The weight of the several cokes for this constant bed varied from 180 to 230 pounds, showing a considerable range in specific gravity—from the very light to the heavy cokes.

Metal weighing four times this weight of coke was charged on this bed, to conform to the general custom of foundries, and the remaining successive charges of metal and coke were divided into four parts, so as to preserve the total ratio of 7 to 1, the coke charges varying from 50 to 62 pounds and the metal charges correspondingly. The blast was kept at about 7 ounces, and the time when the first iron appeared at the spout was noted. This time, which was five to fifteen minutes, was interesting as indicating how the coke behaved in burning and in allowing the iron to come into the melting zone. With the best results the iron came in seven to ten minutes.

Necessarily for the extremely light and very heavy cokes such melting practice would mean disaster, and in fact the melting loss did point very markedly to such a result. Possibly this may also convince many foundrymen who still think it impossible to burn up iron in the cupola. The results showed the melting losses to be from 3.2 to 52.5 per cent. of the metal charged. The cupola was continually slagged off, but in the worst case so much slag was made that it flooded the tuyeres and effectually stopped operations. When the bottom was dropped no metal was found remaining. It was evident that the lighter varieties of coke burned away so rapidly that the metal came to the lower portion of the melting zone much faster than it should have come. Moreover, as the original bed went down unduly for the melting of the first charge the subsequent coke charges did not bring the bed up to proper level again, and hence a Bessemerizing of the metal took place almost from the very beginning.

In tests of the very heavy cokes it was necessary to wait a good while before the bed had burned low enough to begin melting. Necessarily at the fixed ratio of 4 to 1 the first charge of metal on the heavy coke bed was very heavy. In this case also there was an undue lowering of the bed by the heavy metal charge after the surplus coke had burned off to begin melting. What was worse, however, was that the heavy coke bed took so large a part of the total amount to be used that the upper coke charges were necessarily very small, and the practical result was not only burned metal, but an insufficient amount of coke toward the end to continue the heat, so that the bottom had to be dropped. The general result of these heats with very heavy coke was burned iron for the beginning and unmelted iron in the cupola drop.

It may be seen, therefore, that when the melting process with a normal coke gives good results it does not necessarily follow that every other coke will do likewise; yet this is what the foundryman practically assumes when he changes his coke without making trial heats to see how to use it.

It should be understood that the clean, silvery appearance of beehive-oven coke as compared with the dull black cast of the retort-oven product results principally from the manner of quenching. In the beehive the quenching is done within the oven, and as little water as possible is used. In the retort oven the red-hot charge is forced out and deluged with streams of water as it drops into the receptacles for the coke. Consequently the retort-oven coke contains much more water

than the beehive product. The formation of steam in the cells and the condensation and consequent drawing in of the water seem to hold it tight within, and when once water is thus included it remains. Coke exposed to rain will drain off the water to a great extent, but the occluded water of quenching stays. In practice, coke with a little moisture does no great harm in the cupola, although the bed coke must be dry. There is, of course, a thermal loss in driving moisture off, just as there is a great saving in the blast furnace in the use of artificially dried instead of natural air.

Coke producers should therefore be urged to make thorough melting tests with their coke, so that when selling it they can advise foundrymen how to get the best results with it. This plan would save enormous trouble.

(To be continued.)

Moulding a Tup in Loam.

By Percy Jones.

Every foundry at times suffers the ill-luck of having large castings turning out wasters, not always through inexperienced workmen, for the best of moulders will occasionally produce wasters. When such a thing does occur, the first necessity is to break the article up, so that it will go into the cupola to be melted down again. The ordinary pig hammer is of no use for large work, and what is known as the "tup" has to be brought into play. It is the writer's intention to describe one method of moulding a tup for the above purpose—a method that is economical, easy of execution, and productive of good results. The moulding and process of making is in itself what would be termed in any foundry a "plain job," and so it is, once the right method is understood, and the proper tools to work with are at hand. By the writer's method the mould is made by means of sweep and spindle (Figs. 1 and 2), with two open sand plates (Figs. 3 and 5) instead of box parts. Fig. 2 shows the tup in itself with the sweep board fastened to the spindle in the centring block.

The first thing to do is to make a level bed, the diameter of the plates, on the foundry floor, using straight edges for the purpose. The centring block is placed as shown in Fig. 2, exactly in the centre of this bed, dead level, and the plate shown in Fig. 3 is then placed also exactly over and perfectly level with the centring block. The spindle is inserted and the sweep fastened on to it. Bricks B (Fig. 4) are then laid in a loam mixture. It will be noticed that an opening is left between all the bricks as at C (Fig. 4). This is partly due to the impossibility of making close joints with ordinary bricks; but these open joints can be filled and rammed with small cinders, using the end of a flat file for the purpose. These small cinders act as vents, for the escape of the steam and gases, but the cinders should be riddled through a ¼-in. riddle and afterwards through a ½-in. riddle so as to take out all those under ¼ in. or over ½ in. in size.

Having done this, the top of the bricks are freed from the small ashes and another course of loam mixture is daubed over them as before. It will be noticed in Fig. 4 that in building up the bricks for the bottom half of the dome part, they will have to be placed a little further back each time, until the centre line is reached; then they will have to be brought forward a little each time, until the dome part is complete. Having proceeded in this manner until the top has been reached, the entire surface is finished off with fine loam, which will give it a nice appearance. This part of the mould is now ready for the stove; having taken out the spindle and board it is placed by the crane on the stove carriage to dry.

The other plate (Fig. 5), which is to form the top part and cover the mould, is now covered with the loam mixture, finishing it off with a flat piece of wood and finer loam. This is also placed in the stove to dry. When these are dry, the loam will be found to have cracked and opened. These cracks should be cleaned out with the pointed end of a file, and filled in with loam. Having done this, the mould can be blackwashed, using a swab for the purpose, and placed again in the stove to dry. It is then necessary to dig out a hole in the foundry floor to receive the entire mould, making a level bed at the bottom. The first made part of the mould is then lowered down and rammed all round the outside walls to prevent bursting during casting. When doing this, great care must be taken to get the vent away.

The mould is then ready for the top part. The staple is fastened through the slot made to receive it, by placing an iron rod through the eye of the staple and across the top side of the plate, so that it will be suspended in the mould, not being able to move the least during casting. The top part is placed exactly over the other, and both parts are clamped together by four long clamps which fit on the lugs of the top and bottom plates. The runner and riser pegs are inserted and made up, and the tup is ready to be cast. A tup of strength, usefulness, and cheapness can be made in this way, which does away with making a wooden pattern.

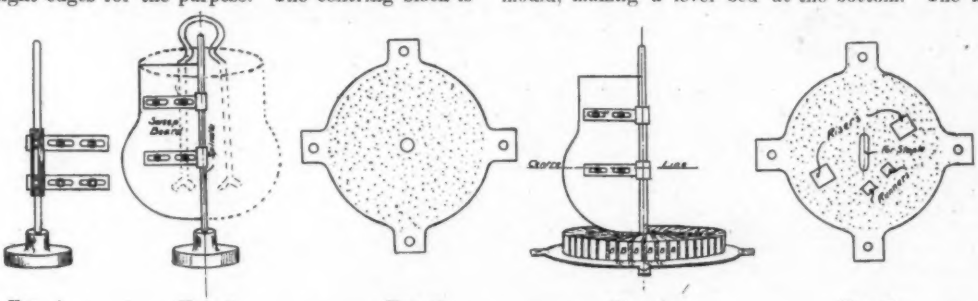


FIG. 1. FIG. 2. FIG. 3. FIG. 4. FIG. 5.

MOULDING A CAST-IRON TUP IN LOAM.

The Installation and Equipment of a Small Brass Foundry.

By A. Napier.

(*Continued from page* 149.)

Having arranged the general lay-out of the foundry, the disposition of the furnaces and other departments, and the style of furnace to be used, there are a number of minor details to be attended to. In passing, also, a word may be given regarding the ventilation of the building—a very important matter both as regards the health of the workers and the success of the foundry operations. The importance of ventilation in the brass foundry is better understood and appreciated to-day than was the case a few years ago; for the rapid removal from the foundry of the fumes incidental on brass casting has been insisted on in recent Government Regulations. Various ventilating devices and systems are available for handling the fumes during pouring and melting, but apart from these it is necessary to provide for a free current of air through the foundry—not sufficient to cause an objectionable draught, but so that the air may be kept fresh for the workmen. This can be done by providing openings at the floor level and also in the roof.

Where patent melting furnaces are installed, hoods or other apparatus are frequently supplied for taking away the fumes, but those fumes resulting from the oxidation of zinc during pouring cannot be well avoided, and require to be quickly dispersed by ordinary ventilating means, such as fans or similar apparatus, where the natural current of air passing through the foundry is found insufficient.

As regards the dressing room for the castings as they come from the moulds, this should be fitted with a bench, a few vices, and small tools for trimming the castings. A spruce cutter can often, with advantage, be also installed, in addition to the abrasive wheels for grinding.

As regards the drying stoves for moulds and cores, the size of the work to be dealt with will largely govern the size of these. For cores there are a number of handy ovens obtainable for heating by gas, if that fuel is available, though a coke fire, of course, may be employed. The essential is to have an oven which will easily accommodate all the cores which are likely to be required at one time, the fuel arrangements being such as will allow the maintenance of a maximum temperature of 400 degrees F. A similar but larger drying stove should be provided for drying moulds. The fuel for heating may be, as before, either gas or coke. A steam jacket, also, forms an alternative means for heating the drying stove, and has the advantage of cleanliness and convenience. The stove does not differ in essentials from those for iron moulds. It may be constructed from sheet iron, or brick may be used if the heat is obtained from a fire inside the structure. Waste heat from the furnaces may also, in some cases, be utilised for heating these stoves.

A tank of water for plunging the castings should also be provided, for while many castings are only sprayed with water on being taken from the mould, for certain classes of work they are plunged while still hot into a tank of water, the object being to obtain softer castings and improve the grain. This, however, is a separate subject, and not strictly to be considered under the heading of design and installation. Plunging castings that are cored has also the effect of blowing out the cores, and thus facilitating the operation of fettling.

A department which should form an adjunct to the actual foundry comprises the dipping and colouring room and the lacquering rooms. Needless to say, the latter requires to be kept clean and free from the dirt and smoke of the foundry. This work, however, is distinct from the actual foundry, and will not be dealt with here. The same applies to the pattern-making department, which subject requires treating separately.

A selection of crucible tongs to fit each size of crucible employed must be supplied, and in connection with this it may be mentioned that the tongs should be regularly inspected to insure their fit. Through constant use, and as the shape of the crucible alters with use, the fit of the tongs becomes less perfect, and the crucibles are liable to premature failure through badly fitting tongs causing undue pressure. It is, therefore, advisable to have two or more tongs for each size of crucible, one to fit when the pots are new, and the others to accommodate them as they become more and more worn and out of shape.

The care of crucibles is an important matter in the brass foundry, for while with careful handling a pot melting brass may give up to 40 heats, by misuse the life may be reduced to a very few heats. The life of a crucible, however, will depend on the metal being melted and on the rate of melting. Where quick melting under forced draught is the rule, the effect on the crucible is worse than when slower melting obtains, the ultimate heat of the furnace also being an influential factor. Either plumbago or Stourbridge fireclay may be used for the crucibles, the latter being the cheaper in the first cost, though less durable. It is important in brass founding, as in steel work, to use good crucibles which will neither corrode nor unduly deteriorate through the changes of temperature to which they are subjected. They should be annealed thoroughly for several days at a moderate heat, ranging about 220 degrees F., or about the same as that employed for the core-drying stove. This ensures all the moisture being driven out, and prevents cracking in use. With large crucibles it is advisable to heat them for six or eight hours after annealing, mouth downwards over a slow fire. After the metal has been poured from the pot it should be drained quite clear of both metal and dross. If any attempt is made to remove metal that has cooled in the pot, it will probably result in damage to the crucible. After use the crucible should be stored in a warm dry place. While small crucibles may be poured by means of the tongs used to draw them out of the fire, a pouring shank is generally employed, this consisting of a form of tongs which encircles the ladle horizontally, and is held in position by passing a ring over the handles at one end as they come together, giving thus a handle at each end, by means of which two men can carry and pour the metal.

In order to save unnecessary labour, the sand heap

from which the moulders work should be placed in a convenient position. For small work a moulding tub should be provided, this consisting of a strongly-made wooden box about 3 ft. from back to front, and about 21 in. deep, provided with sliding bars and a number of 1-in. boards the size of the moulding boxes. The length of the tub will, of course, be governed by the space available and the requirements of the work.

For brass work the moulding boxes are generally smaller than the usual run of iron-foundry boxes. A useful style of box has the sides hollowed out to form a long V groove round each half of the box. This formation retains the sand better than square sides, and the moulds are not so liable to break up or fall out. The ordinary square-sided box with a fillet round the edge, however, serves very well. For some work also the snap flask is used. When large work is to be handled the boxes may have cross bars cast across them, or wrought-iron bars may be cast in a similar manner to the bars in iron foundry boxes. For small flat work oak moulding flasks fitted with top and bottom boards and screw clamps are suitable. After ramming, the boards are placed top and bottom of the flask, and the whole clamped together for pouring. Holes for the gates are provided in the ends of the flask.

Finally, it is important that preparations should be made for collecting the skimmings from the molten metal. When it is cleaned or skimmed prior to pouring, the refuse from that and similar process should be placed in a skimming box for further treatment. The metallic content of this apparently waste matter is high, and the value represented considerable. The refuse may generally be disposed of at a fair price to smelters, or in some cases plant may be installed to deal with it. Not infrequently metal may be splashed on to the floor or sand, and unless care is taken to collect it, it will become wasted. All sand which has got such metal particles mixed with it should be gathered, fine sieved, and washed to collect the metal. This, although dirty, can be melted down with a suitable flux, and though not, perhaps, suitable for good work, may be usefully employed for some purposes.

Moulding Box for Large Hollow-Ware.

By A. Hamilton.

The writer recently completed an order for three sets of castings, each set consisting of bottom, intermediate frame, and top frame, the outside size being 3 ft. 6 in. × 3 ft. 6 in. × 18 in. deep. and each part weighing approximately seven cwt. The difficulty of making the castings without crane or such tackle for lifting and casting had, however, to be faced, and accordingly the moulding box described herewith was constructed, which did away with all lifting with the exception of the top part.

After completing the pattern, which was screwed together at the corners, all bosses on the outside were screwed from inside and unscrewed when the outside was rammed up. First was made the bottom part of the box with two sets of double snugs on each side with a hole cast in for a ¾-in. bolt, the centre of the bolt hole being ¾ in. below the parting joint, to ensure the mould leaving the pattern clean. Next was made the mid-part, which consisted of four plates one inch deeper than the pattern, each plate having two snugs cast on to correspond with the double snugs on the bottom part (see F, Fig. 1). The plates had also lugs cast on at each end to bolt all four together, ¾ in. bolts being used, as shown at C and D, Fig. 1. Lugs E were also cast on top of each plate for guiding the top part.

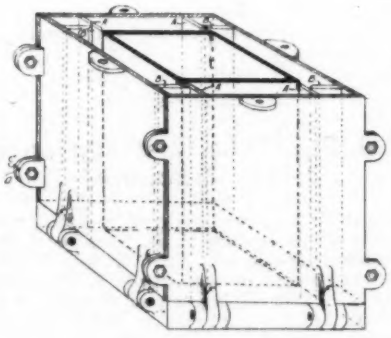


Fig. 1.—Closed Box.

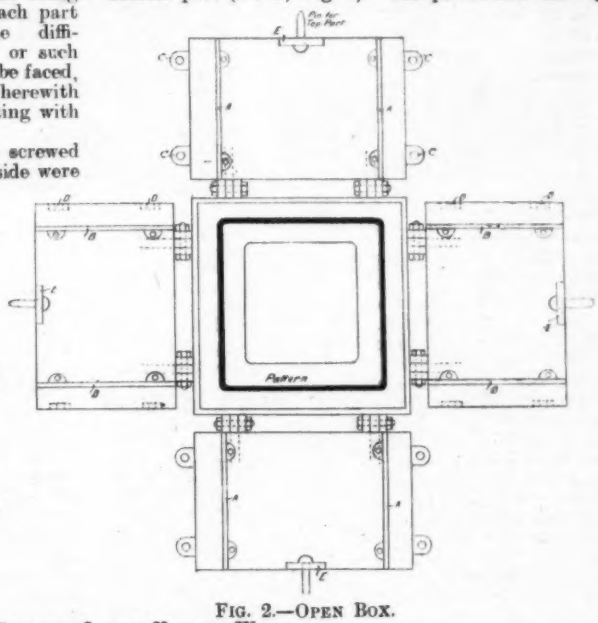


Fig. 2.—Open Box.

Moulding Box for Large Hollow-Ware.

The most important parts of the box were the cheeks A and B (see Figs. 1 and 2). After the box was cast and properly fitted together, the pattern was put into

position on top of the bottom part, one inch above the joint; the cheeks A tapered to a knife-edge, as shown in Fig. 1, were fitted close up to the corner of the pattern and bolted to the end plates as shown in Fig. 2. The cheeks B were fitted in the same manner, but hard up to cheeks A, one inch from the pattern, as shown in Fig. 1. The top part was quite ordinary.

Moulding was commenced in the usual way by putting down the bottom part on a level bed. It was filled up with sand one inch above the joint, and the pattern put down. The plates were tried up, and everything being correct the plates were laid back and the bottom parting made, tapering the parting from the bottom edge of the pattern to the edge of the bottom part. The four plates (mid part) were then placed into position, bolted firmly together, and the outside of the mould rammed up first. This done, all

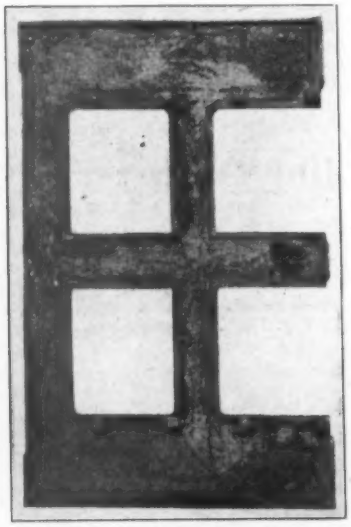


FIG. 1.—BOILER FRONT, ⅜ IN. THICK, MADE ON A JARRING MACHINE.

FIG. .—THE MOULD FROM WHICH THE CASTING WAS MADE.

screws were unscrewed from the inside, leaving all bosses, etc., free. After completing the core the top parting was made and the top part put on and rammed up, then parted. The bolts that held the mid part together were unscrewed and the plates swung back. The pattern was unscrewed at the corners and taken away from the core.

After finishing off the mould and core the plates were swung back, bolted together again and everything made secure. A space between the cheeks at the corners will be noticed. This was filled up with sand and rammed firmly. There was no danger of sand getting into the mould, as the cheeks B were properly fitted to the cheeks A. The top part was then put on. This was the heaviest part and required ten men; two men did the rest.

The three sets (or nine castings) were finished without accident, all the castings being good. The bottom part was never lifted or the mid part unscrewed from the bottom part. In doing this job in the manner described, the writer estimates that quite 25 per cent. was saved in the cost of moulding, and also the pattern making was reduced to a minimum.

It is reported that the locomotive works at Kingston (Ontario), employing 600 hands, have been sold to a British syndicate.

British Foundrymen's Association Lancashire Branch.

The closing meeting of the 1910-1911 session of the Lancashire Branch was held on Saturday, May 6th, 1911, at the Municipal School of Technology, Manchester, Mr. R. W. Kenyon presiding. The first business was the election of officers for the ensuing year, when the following appointments were made: President, Mr. F. Penlington, Manchester; Vice-Presidents, Messrs. J. Simkiss, T. W. Markland, W. H. Sherburn, M.R.S.A. and W. Wright; Hon. Secretary, Mr. H. Sherburn, Rotherwood, Stockton Heath, Warrington. The vacancies on the Committee were filled as follows: Messrs. R. W. Kenyon, A. Harrison, H. S. Skelton, F. Andrew, F. W. Robinson, and W. McVie. Messrs. T. H. Hawley and H. Grandidge were appointed Auditors.

High appreciation was expressed and hearty votes of thanks were accorded to the retiring President and other officers for past services, on the motion of Mr. Hawley, seconded by Mr. Andrew. It was decided to hold extra propaganda meetings in various Lancashire towns during next session, with a view to stimulating interest in the districts where the Association is not so well known. The arrangements for the work were left in the hands of the Committee.

Following the annual business, a very interesting discussion was raised on a foundry problem, introduced by Mr. Smith, in the absence of Mr. Cordingley, who was prevented by illness from giving his Paper on "Foundry Problems."

Moulding Thin Castings on a Jarring Machine.

The mould for an exceptionally thin casting was recently made at the foundry of the Chandler & Taylor Company, Indianapolis, Ind., on a three-cylinder jarring machine supplied by the Arcade Mfg. Company, Freeport, Ill. This casting, a view of which is given in Fig. 1, was a boiler front and the mould in which it was made is illustrated in Fig. 2.

While there is nothing special about the size of the casting, which measures 6 x 8 ft., its thickness is remarkable, as it is only ⅜ in. Making these moulds with the aid of a jarring machine has resulted in at least doubling the output of the foundry. Prior to the installation of this machine only one of these castings could be made per day. At the present time it is possible for one man to make three of these in a day, a result which is partly attributable to the use of moulding machines and also to the fact that the cope and the drag are made separately, the former not being put on the mould until the drag is completed. ("Iron Age.")

The Small Jobbing Foundry.

By Walter J. May.

Whether the small jobbing foundry is carried on as an individual concern or as an adjunct to a works making other things and which requires the foundry for convenience only, it is generally the case that it is badly equipped for turning out work to the best advantage. In a small place the range of work which comes in is very wide, and, practically, all metals and alloys have to be handled from time to time. Unless the moulders are pretty smart they are liable to have to refuse work, owing to the lack of some necessary appliance. Of course, in a small place there is a limit to the weight of castings required to be made, but this does not limit size, and anything from a 1 lb. sashweight to a 6ft. by 4 ft. gate may be called for in architectural work, while in machinery anything from a small wheel to the side frame of a fairly large machine may come in; and yet the weight limit may be as low as 5 cwt. to 6 cwt. for one piece in iron, while in brass or gunmetal castings anywhere from a few ounces to perhaps 250 lbs. will be called for.

To make special flasks is difficult in many cases, and, indeed, the appliances for lifting heavy flasks are too often absent, and for this reason it is often compulsory to refuse work which might otherwise be done fairly well. In arranging lifting apparatus, although an overhead traveller may not be possible, it is desirable that sufficiently strong attachments for block tackle should be provided, and if nothing else can be arranged an overhead runway with a carriage and blocks of sufficient power should form a means of conveyance from the cupola to the part of the floor where heavy castings are made, while, with a little care, this runway with its lifting tackle can be adapted for handling large flasks if common sense is used.

The first question to be considered is the melting of the metal. Usually for iron the cupola is the cheapest furnace, about 10 lbs. of coke per 1 cwt. of iron being a fair quantity to use where the cupola and fan work properly. A plain cylindrical cupola of from 14 in. to 16 in. internal diameter is generally sufficient for a small foundry, but, of course, larger sizes can be used where the requirements of casting necessitate more than, say, one ton of iron at each cast.

For brass and other alloys crucible melting has to be done, and it is well to have two or more furnaces of sizes to take different sized crucibles. Whether these be simply natural draught furnaces built of firebrick, patent furnaces for natural draught, or mechanical furnaces having forced draught, will depend largely on the financial position of the person equipping the foundry. The appliances used in each foundry must, necessarily, depend on its particular requirements.

The floor, of course, must be of sufficient area to allow of the work being done on it, and, while too small a space cannot be worked advantageously, there is no reason why a large floor should not be utilised, for by having plenty of floor space there can be fewer casts, and this tends to economy. If a cast is made each day there is a loss of moulder's time in actual moulding, but if the floor is cast up twice a week this loss is greatly reduced. This is, however, a matter of detail only to be locally determined, but, at the same time, it has to be carefully considered when arranging a foundry. In any case space must be kept for brass and other alloys, this being quite distinct from the space allotted to iron. If this is not done trouble soon occurs owing to the dirt from the brass and other metals getting into the sand used in the iron moulds.

A fair number of flasks should be provided, each set of six or twelve flasks of ordinary size having the parts interchangeable, and the middle parts, say one each of 2 in., 3 in., 4 in., 5 in., and 6 in. depth, should be provided so that three- or four-part boxes may be built up when this makes moulding easier. Beyond flasks of an area likely to be in common use, a few of extra size will be necessary occasionally, and often it is better to make these when required, as it is very easy to have a good many tons of flasks on hand without their being used for years, and as flasks cost £5 or £6 per ton to cast a lot of capital can soon be swallowed up. Care should be taken in moulding flask parts to ensure that the edges are square, and that the legs come in the right place, closed moulds always being preferable to open ones when making flasks. The holes for the pins should be drilled by a template, to ensure that all parts, in each set of flasks, are interchangeable. All castings of this kind should be strong enough to be stiff without being clumsy, the size and shape of the flask determining its thickness.

The supply of loose plant in the way of beams, chains, and other things which are often in demand, should be sufficient for the work taken in hand, and there should be a fixed place for everything, care being taken that each article is replaced as soon as done with. This is important with all things, and unless "a place for everything, and everything in its place," is a maxim strictly adhered to, very considerable leakages and waste must ensue.

Usable stores, such as sands, blackings, and the like should be stored in proper bins and boxes, etc., according to what is being dealt with, and facing sands, parting sand, and the like should be prepared in spare time and stored ready for the moulders. Such things as blackings should be handed out to the moulders in tins, and some note should be taken of the quantity issued, for, although a moulder will not often waste his materials, if tins are scarce there is often an inducement to throw out blacking to substitute something else. For this reason it is usually a good plan to get some pound and half-pound tins, similar to those used for cocoa, as these cost little, while they save a lot.

Considerable care has to be taken with metals where small foundries are concerned, because only small quantities can usually be purchased, and these have to be dealt with in a manner to prevent loss. Iron should be kept in bins so far as new metal is concerned, and these bins must be labelled or marked in such a way as to identify their contents. More valuable metals, such as tin, copper, aluminium, and the like have to be stored and dealt with cautiously, as they are too costly to waste, while alloys should be kept in boxes or bins, with the content of the alloy carefully marked on them.

Scrap iron should be sorted carefully before use, as with ordinary scrap there will usually be found several qualities, and each of these will have its uses, but, generally, it is desirable to have an outlet for the poorest stuff, such things as sash-weights, boat-ballast, and the like providing a not unprofitable business if there is a sale for them.

Scrap alloys should be carefully sorted, and it is then a good plan to run them down in large crucibles, or in an air furnace, so as to obtain, as far as possible, an even admixture of the content; ingots from this run-down scrap produce more regular castings than

if the scrap is melted as wanted. Some things, of course, should only be touched by an expert, such things as fine aluminium scrap, mixed antifriction metals and the like being out of place in the ordinary small foundry, and, for that matter, in many large ones as well.

In a small foundry the men and lads employed have a great bearing on both the mechanical results and the profits, and in no case does it pay to employ indifferent workmen. The wages account will, of course, be higher where the best men are employed, but, on the other hand, the work turned out will be better, a point of much importance when making castings for sale. Clean, well-dressed castings, which are true to pattern, always produces repeat orders, and these should be the things produced.

Foundry Plant and Equipment.

The Grimes Roll-Over Core Machine.

The jolt-ramming roll-over core-making machine illustrated herewith, made by the Midland Machine Company, Detroit, Mich., U.S.A., has been designed for the producing of small moulds and for the economical production of cores, both regular and special cores of various shapes and sizes. Fig. 1 shows an air cooled cylinder mounted on a plate and fastened to the rotating table of the Grimes machine, with a completed mould at the side. The air-cooled cylinder is jolt rammed and drawn without wires to hold the ribs. In Fig. 2 the mould is shown after it has been jolted with the foot lever and clamped, ready to turn over. In Fig. 3 the table is raised and the flask is being turned, the centre of gravity of the core being the centre of rotation. Fig. 4 shows the core on the two receiving arms and the core box raised from the core by pressing on the foot lever.

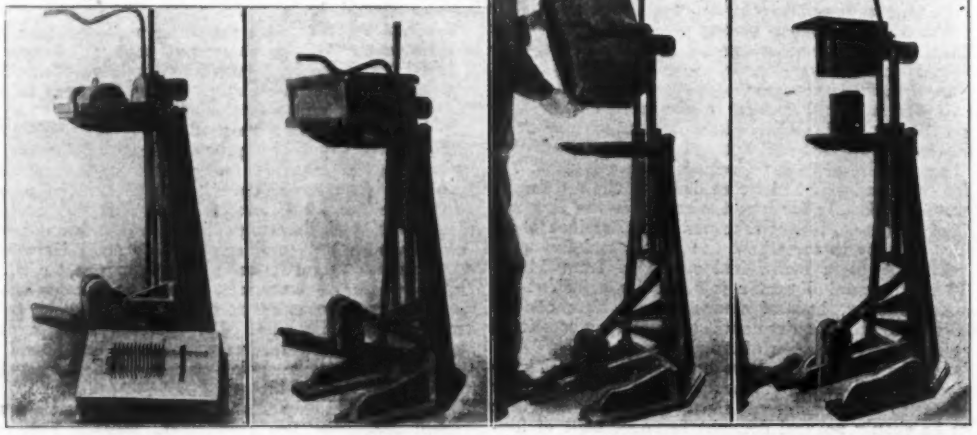


FIG. 1.—CORE-MACHINE, WITH PATTERN. FIG. 2.—CORE-BOX, CLAMPED AFTER RAMMING. FIG. 3.—CORE BEING TURNED. FIG. 4.—BOX DRAWN OFF CORE.

THE GRIMES ROLL-OVER CORE MAKING MACHINE.

For long work the receiving arms are swung out of the way and the core box turned without raising the table. The machine has three bars rigidly fastened at top and bottom, which form the sliding guides. The top connection between these bars forms the bearing for the long trunnion for the revolving table. For small light work the clamp can be taken off and the plate held in place by hand, while rolling over the core. The cam and lever arrangement is counterweighted, for ease of operating the machine. The machine is built in two sizes, with a lift of 10 in., which makes it possible to handle a considerable variety of work, both as a moulding machine and a core machine.

The New Haven Sand-Blast Barrel.

A unique sand-blast rolling barrel is illustrated herewith. In this apparatus the sand mixer is constructed within the barrel, making the whole quite self-contained. This form of construction has several advantages, amongst which are that there is no sand hose to wear out and replace, no extra room required for the sand-mixer, and no labour expense to replace the sand or steel shot in the mixer after once used, the barrel automatically replacing the sand in the hopper inside the barrel. The sand or steel shot is used over and over again until it becomes dust, and is carried away by the exhaust. The nozzles may be replaced at a very small expense, and four to six of these nozzles are used in one barrel.

The complete apparatus weighs nearly 4,000 lbs., having a solid cast-iron frame to support the barrel. The head of the barrel is stationary, and the barrel revolves around it, enclosing the nozzles ejecting sand under air pressure ranging from 40 to 80 lbs. No dust whatever comes from the barrel while it is in motion. The apparatus may be placed anywhere desired, the actual space covered being 5½ square feet.

Unlike the ordinary tumbling barrel, this apparatus makes only three revolutions per minute, thereby diminishing the breakage on the most delicate castings to the smallest degree possible, and not rounding the edges as is the case when tumbled with stars, etc.

As regards the details of construction, the inner barrel B (Fig. 3) is made from heavy sheet steel, having a number of holes which allow the sand after coming from the blast nozzles F and striking the castings to fall through at the bottom of the inner barrel B to the outer shell A. As the barrel revolves the sand or steel shot falls into the buckets C, and is carried to the top of the barrel, where by its own gravitation, it falls back through the holes which it entered, passing through the screen E, which removes all foreign substances in the sand, into the sand-hopper D ready to be used over again. G indicates an exhaust pipe for removing dust, and H a removable guard plate for the stationary head.

As regards the air pressure, either high or low pressure may be used, but between 40 and 80 lbs. is recommended, using from 40 to 60 lbs. with 3/16 in. air nozzles, or 80 lbs. with six ¼-in. air nozzles.

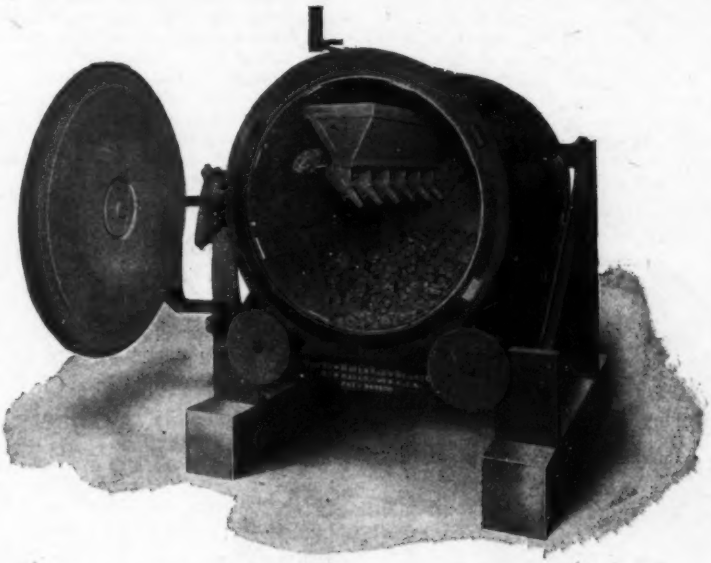


FIG. 1.—NEW HAVEN SAND-BLAST BARREL. FRONT VIEW, OPEN.

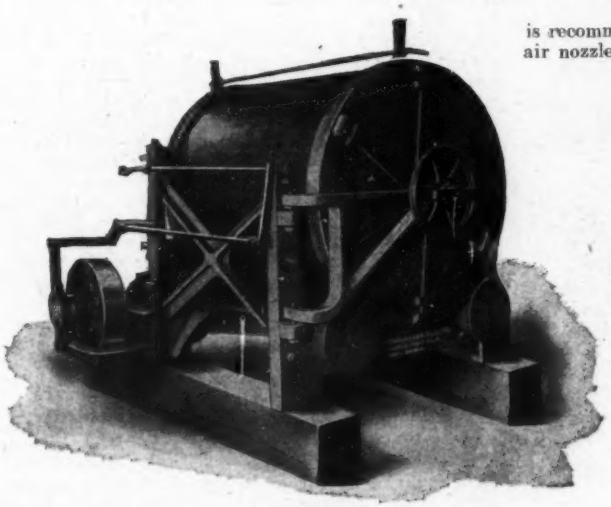
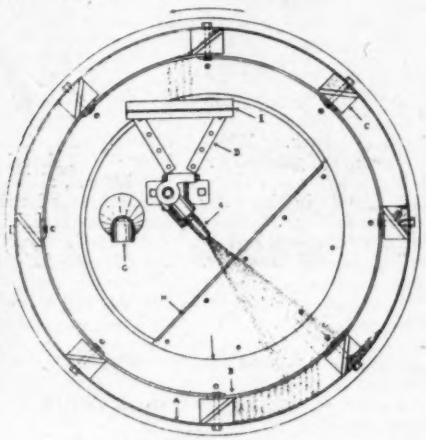


FIG. 2.—NEW HAVEN SAND-BLAST BARREL. FRONT VIEW.



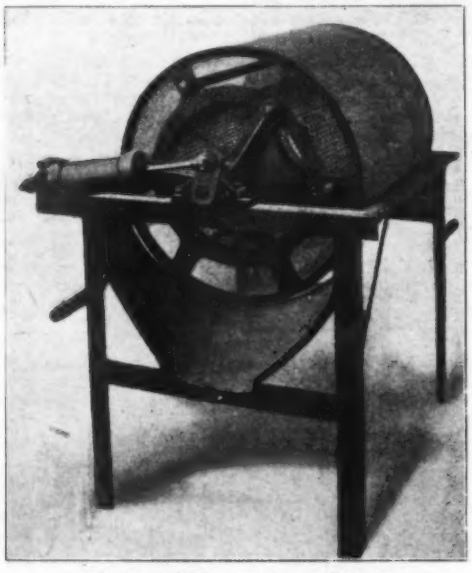
NEW HAVEN SAND-BLAST BARREL. DRAWING SHOWING DETAILS OF CONSTRUCTION.

Rotary Sand Sifter.

The foundry sand riddling machine shown herewith consists of two wire cloth cylinders 30 in. long, mounted in a heavy revolving frame. The mesh of the inner cylinder, which is 14 in. in diameter, is ½ in., while the 24-in. outer cylinder can be supplied with

whatever size of mesh is required, it being only the work of a few minutes to change the mesh. The sand is shovelled into the inner cylinder at the far end and both cylinders are rotated by the piston at the opposite end. By a system of lugs and rollers the riddle is jolted four times during each revolution, which breaks the lumps and prevents the sand from clogging the mesh. In this way the sand passes through the sieve as fast as it is thrown in, and as the sieve is tilted slightly the foreign matter passes out through a chute at the end of the machine.

The frame of the machine is constructed of angle steel, which enables it to withstand hard usage, while at the same time two men can easily move it from place to place. The sifter can be operated either by



"ARCADE" ROTARY SAND SIFTER.

hand or power. When hand operation is employed two men are generally required, one to shovel the sand into the sifter and the other to turn it, although there is a handle in the outer rim of the sand entrance so that one man, if necessary, can operate it without help, as the bearings are of the roller type and the cylinder revolves easily. The extreme height of the machine is 3 ft. 9 in. and the extreme width 2 ft. 5 in. The apparatus is made by the Arcade Manufacturing Company, Freeport, Ill., U.S.A.

"F.T.J." Bookshelf.

Assaying and Metallurgical Analysis.

By E. L. Rhead, F.I.C., M.Sc. Tech., and A Humboldt Sexton, F.I.C., F.C.S. London: Longmans, Green & Company, 39, Paternoster Row.

The analysis of materials has become so well recognised as a feature of first-class foundry practice, that no apology is required for bringing the second edition of this book before foundrymen. Whether it be annealing ore, pig-iron, coke, or castings, it is becoming every day more and more of an advantage to have the materials analysed as a check on their quality, and therefore every foundry student should include a knowledge of metallurgical analysis in his training. The authors of the book before us are well known in the metallurgical world, and their experience has been such as to give them a good idea of the requirements of the student. Not for the student alone, however, has this book been prepared, but also for the chemist and assayer, for it is comprehensive enough to include the greater part of the work likely to be required in the laboratory or assay office. The directions for work and the descriptions of processes have been made as concise as possible, to reduce the size of the book; but by the inclusion of the chemical reaction of the metals the reasons for each procedure are made clear. As regards the scheme of the book, the first part is devoted to laboratory appliances and general processes, useful hints rather than full descriptions being given. The second part considers first, under the name of each metal, the materials and products in which its estimation is commonly required, and then the various methods of conducting the assay. The third section deals with metallurgical analysis, and here the authors have endeavoured to group the various substances to be dealt with in a compact manner.

The Production of Malleable Castings.

By Richard Moldenke, Cleveland, Ohio, U.S.A.: The Penton Publishing Company.

Recent years have witnessed many additions to the technical literature of the foundry and other trades, and many of these have proved to be valuable works, but probably none has constituted such a striking departure from the conservative and secretive spirit of the past as the book now before us. One can picture the anger and disgust with which past "malleable" men would have regarded the publication of such a work, for with very few exceptions they would have pronounced such an act to be a step towards the ruin of the malleable castings trade. It is significant of the progress of the age, however, that Dr. Moldenke presents the result of practically a life's study of "malleable" practice—what he describes as the story of the malleable casting as he has seen it develop. At last it is becoming recognised that if the trade is to keep its place in competition with steel, the old and venerable mantle of secrecy—we had almost said ignorance—must be discarded, and the trade must take its stand with the other metallurgical arts, and allow the eye of scientific investigation to probe deep into its mysteries and defects. In keeping with this idea Dr. Moldenke has outlined clearly the characteristics, properties, utility, and the processes of manufacture of malleable castings, explaining very lucidly the essentials in each stage of the procedure. The book is devoted chiefly to the American, or "black-heart" process, and the information given may be accepted as quite authoritative on that practice. The chapter on mixing the charges for malleable iron is very instructive, and shows clearly that, so far from being a haphazard process, mixing for various classes of work may be reduced to a fine art. In connection with melting processes, the author describes the construction and operation of the air furnace and the open-hearth furnace, and in another chapter treats with the use of gas producers in malleable foundries. The subject of annealing, of course, occupies an important chapter, and here the construction of the furnaces and the details of the complete annealing operation are given. Other chapters deal with the use of the pyrometer in the annealing room, the cost of the castings, and the testing of malleable cast iron. Throughout the book there are presented many valuable hints, apart from the ordinary details of procedure, that speak of intimate acquaintance with malleable castings production, and for this particularly the book will be found valuable. A number of drawings and interesting photographs are used to illustrate the work, the latter including views of some typical modern American plant.

Queries.

Estimation of Tin in Gun-Metal.

Can any reader give a simple and inexpensive test for arriving at the percentage of tin in a gun-metal alloy?—"R. K."

Hot Water Radiators.

The writer desires to obtain information on the manufacture of hot-water radiators, the nature of the core-binder, and the preparation of the cores and moulding sand, and the methods employed to secure good and cheap castings.—"S. H."

Cupola with Drop-Bottom and Receiver.

Has a drop-bottom cupola, working in conjunction with a receiver, any advantage over the ordinary type? There should be an economy in the coke bed, but could metal be delivered to the ladle as hot from the receiver as from an ordinary cupola?—"W. G. C."

Answer.—The use of a drop-bottom has more advantages than disadvantages, the former including greater ease in dumping at the close of a day's heat. As regards a receiver, this apparatus is generally designed so that the waste heat of the cupola is utilised in the receiver. Where the metal is required to be uniform the apparatus has the advantage of acting as a mixer. As to loss of heat, this should not be sufficient to outweigh the advantages of a receiver if the quantities of metal required at one pouring are great; in fact, the heat loss should not be materially greater than is involved in holding a quantity of metal in the cupola for a large pouring.

Foundry Roofs and Stoves.

Will readers give their experience with the "Belfast" roofing for covering a foundry? Can it safely be employed for a foundry, despite the sparks which escape from the top of the cupola?

Also, what are the advantages or otherwise of gas-fired stoves? Further, can electrically-driven cranes be made sufficiently delicate for jointing moulds, placing cores, etc.? That is, can hoisting and lowering be done as carefully as by hand?—"W. G. C."

Polish on Iron Patterns.

Can any reader give me particulars as to the best method of getting a good polish on iron patterns and pattern plates; also as to any varnish, etc., suitable for the work?—"J.W.W."

Titanium in Iron and steel.

The effect of titanium in iron and steel manufacture appears to be as a powerful deoxidiser and denitrogeniser. It does not appear to act as an alloy in the ordinary sense of the term, but as a purifier. If ferro-titanium be used it is more advantageous to use an alloy with a comparatively low percentage of titanium, on account of the increased solubility of such ferro-titanium, but titanium in higher percentages is also manufactured alloyed with suitable proportions of aluminium and iron and aluminium and silicon, suitable for both steel and iron manufacture. Titanium is being extensively used in some of the best grades of high speed steels. The addition of about 0.12 to 0.16 per cent. is claimed to considerably increase the cutting power of these steels.

Trade Talk.

THE RUSTLESS IRON COMPANY have removed from the Midland Works to the Trico Works, Keighley.

MESSRS. DONOVAN & COMPANY, engineers, have removed from 12, Barwick Street, Birmingham, to 47, Cornwall Street, Birmingham.

THE offices of the National Metal Company have been removed from 117-121, Holdsworth Street, Glasgow, to 193, Broomloan Road, Govan.

ERNEST SCOTT & COMPANY, LIMITED, engineers, have removed their head office from Talbot Court, Gracechurch Street, London, E.C., to Kingsway House, W.C.

E. G. WRIGLEY & COMPANY, LIMITED, engineers, of the Foundry Lane Works, Soho, Birmingham, have established a branch at 60, Pilgrim Street, Newcastle-on-Tyne.

THE Highways Committee of the London County Council have recommended the acceptance of the tender of Hadfield's Steel Foundry Company, Limited, for the supply of certain track work for the trams, at a cost of £13,245.

CAMMELL, LAIRD & COMPANY, LIMITED, have lately installed at their Cyclops Works, Sheffield, a slab mould, which it is claimed will produce the largest ingots made. The mould weighs 110 tons, and the ingot will weigh 120 tons.

THE partnership heretofore subsisting between Messrs. J. Downham and J. Byrom, carrying on business as engineers and machinists, at Fountain Street, Bury, under the style of John Downham & Company, has been dissolved.

THE firm of Rennie's Steel Casting Company, Tolcross, Glasgow, has been dissolved by the retirement of Mr. T. B. Rennie. The business will be continued under the same name by Mr. D. Rennie and Mr. G. Rennie, who will discharge the liabilities.

THE Tinol branch of the business of Messrs. Neville, Williams & Company, 80A, Southwark Street, S.E., has been converted into a limited company under the style of Bi-Metals, Limited. Messrs. Neville, Williams & Company are continuing their engineering business as usual.

JAMES KEITH & BLACKMAN COMPANY, LIMITED, High Street, and Applegate Foundries, Arbroath, are making extensive additions to their premises owing to pressure of work. Negotiations are also preceeding for the acquisition of adjoining ground on which to erect new premises.

THE members of the Derby Society of Engineers brought a successful session to a close on May 12, when a paper on "Electric Steel Furnaces" was read and discussed. In the unavoidable absence of the author, Mr. John Harden, of London, the paper was read by Mr. E. C. Ibbotson, of Sheffield.

A PETITION has been presented to the Second Division of the Edinburgh Court of Session by Mr. D. Duncan, one of the partners of Messrs. Simpson & Company, scrap metal and machinery merchants, 19, Anderston Quay, Dublin, craving the Court to dissolve the firm. Lord Cullen has ordered intimation of the petition.

WM. T. AVERY, LIMITED, have successfully tendered to the Leeds Corporation to place one of their patent tram weighbridges at their sewage works. The platform measures 5 ft. by 2 ft. 6in., with a weighing capacity of 5 tons by 7 lbs. divisions, but strengthened to carry locomotives weighing 7 tons. The weighings, with gross and tare, are printed on tickets.

ON May 6 the members of the Middlesbrough and District Association of Foreman Engineers and Chief Draughtsmen held their forty-first annual dinner. The President of the Association (Mr. J. Armstrong) yielded the chair for the evening to Mr. F. A. E. Samuelson, J.P., and he was supported by a gathering which was thoroughly representative of the engineering and allied trades of the district.

MR. H. SPANNAGEL, of Broad Street House, New Broad Street, London, E.C., agent for the Maschinenbau Actiengesellschaft vorm Gebruder Klein, having accepted an appointment with another German engineering firm, at Dortmund, has closed his office at Broad Street House. Veithardt & Company, Limited, 26 and 27, Bush Lane, Cannon Street, London, E.C., have been appointed by M. A. G. v. Gebruder Klein as his successors.

THE members of the Faraday Society met on May 2 at the Institution of Electrical Engineers, Victoria Embankment, W.C., when the following papers were read:—"Hydro-Electric Plants in Norway and their Application to Electrochemical Industry," by Mr. A. Scott-Hansen; "Electro-Metallurgy in the Steel Foundry," by Mr. Verdon Cutts; and "Two Simple Forms of Gas-Pressure Regulators," by Mr. Edgar Stansfield.

AT a recent meeting of the shareholders of the Star Foundry, Limited, resolutions were passed winding up the company voluntarily, appointing Mr. H. Lee, of Blyth, as liquidator, and approving the draft agreement for the sale to the Blyth Shipbuilding and Dry Docks Company, Limited, of the property and undertaking of the Star Foundry, Limited, in consideration partly of cash payments, partly debentures, and partly of partly paid-up shares of the purchasing company.

MESSRS. GEORGE GREEN & COMPANY, of Keighley, Yorks., have shipped a foundry equipment for one of the Japanese dockyards, including a pair of their No. 12 size rapid "Economic" cupolas, fitted with drop bottoms and receivers, each for melting 10 to 12 tons of iron per hour, together with complete sets of lining, 10-ton geared ladle, etc. The same firm have also in hand several complete foundry equipments for new foundries erecting in England and abroad.

A SCHEME of what are called "industrial bursaries" has been formulated by the Commissioners for the Exhibition of 1851, which exists for the purpose of administering the income from the profits of the Great Exhibition. The object of the bursaries is to provide for talented but poor students of science who, on leaving college, are without the means to tide over the usual interval of a year or two before they can obtain remunerative employment in some engineering, chemical, or other manufacturing works.

As indicated by Mr. W. L. Hitchen (chairman of the company), at the last annual meeting of Cammell, Laird & Company, Limited, the head office staffs at Birkenhead have been concentrated in one central building at Tranmere. Mr. R. Ratsey Bevis, the managing director, has established his headquarters at these new premises, and Mr. E. H. Mitchell, the new general manager, and Mr. J. W. P. Laird, recently appointed secretary to the works, also have their offices in the same building. Mr. R. Laird has been appointed as manager of the repairs department, and a suite of offices are to be opened in the Royal Liver Building, where Mr. R. Laird, with a staff, will make his headquarters.

THE annual meeting of the Birmingham section of the Institute of Metals was held on May 2, Mr. G. A. Boeddicker presiding. The report stated that the first session of the section had been very successful. There was a membership of 45, and a considerable increase was to be expected during the coming session. The finances were in a sound condition, there being a balance in hand at the end of the session. To meet a generally-expressed wish, it had been decided to admit associates to the local section. The report was adopted, as also the balance-sheet, which recorded a balance in hand of £5. Officers were elected as follows:—Chairman, Mr. G. A. Boeddicker; secretaries, Messrs. G. G. Poppleton and R. M. Sheppard; and treasurer, Mr. S. M. Hopkins.

THE Home Secretary has issued a notice to the effect that on April 29 he made an order under Section 116 of the Factory and Workshop Act, 1901, applying the provisions of that section, with modifications, to factories and workshops or parts thereof in which the making of iron safes is carried on. The order came into force on June 1. Sections 107 and 108 are also to apply to the making of files, iron and steel cables and chains, iron and steel anchors and grapnels, locks, latches, and keys, brass, etc. The Home Secretary has also issued a notice to the effect that on April 10 last he made an order under sections 107, 108 and 110 of the Factory and Workshop Act, 1901, repealing and re-enacting the Home Work Order of May 23, 1907, with the following extension:—The application of the provisions of sections 107 and 108 to the manufacture of brass and of any articles or parts of articles of brass (including in the term brass any alloy or compound of copper with zinc or tin).

A DIFFICULT operation was successfully carried out by the Midland Railway Company in the early hours of May 1, when two huge castings intended for the battleship "Audacious," now under construction at Messrs. Cammell, Laird's yard at Birkenhead were conveyed from Sheffield to Liverpool. Each of the castings is of about 36 tons weight, and to convey them from the Brightside Foundry and Engineering Company's works at Sheffield to their destination called for the greatest care and calculation. Each casting, when loaded on two 40-ton armour-plate trollies of the Midland Railway Company, measured 12 ft. 4 in. in width, whilst the maximum height from rail level was 10 ft. 7¼ in. The total weight was over 100 tons. At the maximum height the width of the casting was 8 ft. 3 in. Projecting as they did over platforms, the loads had to be kept to a clearance of 4 ft. 0¼ in. above the rails. The difficulty of the undertaking may be understood when it is mentioned that the ordinary width of a load is 9 ft., and that any excess over this is worked under special conditions.

THE second annual report of the International Electro-technical Commission was issued recently. There are now 17 different countries in which an Electro-technical Committee has been formed, in the majority of cases with the assistance of their respective Governments. The latest adherents are Holland and Switzerland. In the near future a small international Committee appointed at a Conference held in Brussels in August, 1910, consisting of Dr. Budde (Germany), Dr. Silvanus Thompson (Great Britain), M. Eric Gerard (Belgium), and M. Brunswick (France) is to meet and discuss the work on nomenclature. This Committee is to prepare a list of terms and definitions dealing with the one subject of electrical machinery, which list is to be ratified by the full meeting of the Commission to be held at Turin in the beginning of September next. Most of the Presidents of the European Committees have signified their intention of being present at Turin, and, if the success which attended the Brussels meeting follows the Commission to Turin, as no doubt it will, the work accomplished should certainly be of a very practical and useful nature.

STATEMENTS have appeared in the daily Press lately to the effect that the British Westinghouse Electric and Manufacturing Company, Limited, Trafford Park, Manchester, is about to cease the manufacture of gas engines. These statements are due to a misunderstanding, and are entirely erroneous. It appears that at some of the previous meetings of the company reference was made to negotiations which were proceeding for a licence to manufacture a large horizontal type of Continental engine in sizes above 1,000 b.h.p. The Board of Directors, after carefully considering the matter, decided that there was not enough work, nor were the prices sufficiently good to warrant the outlay on the machinery and the organisation necessary to enter into the manufacture of this particular type of horizontal engine. Since the inauguration of the company's works at Trafford Park they have been manufacturing vertical gas engines in all sizes up to and including 1,000 b.h.p., known as the Westinghouse vertical tandem engine. In order to more fully meet the requirements of the market below 100 b.h.p., the Board have authorised the building of fourteen sizes of small horizontal type single-cylinder engines.

THE Council of the Institution of Civil Engineers have made arrangements to hold a con-

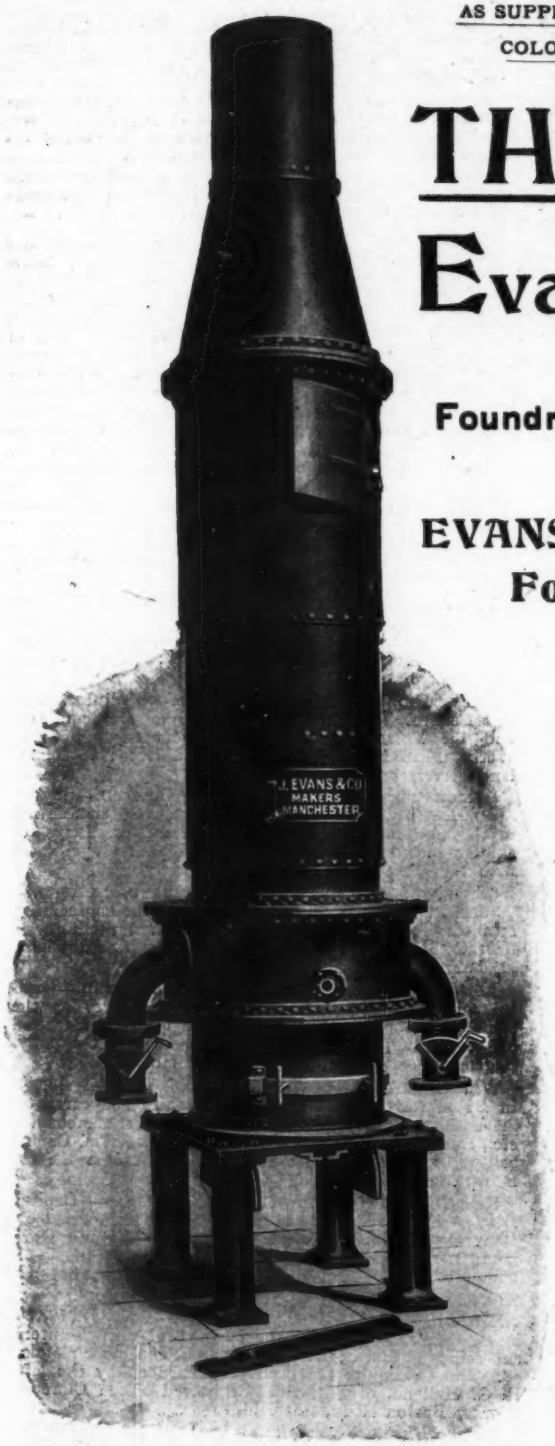
(*Continued on page* 354.)

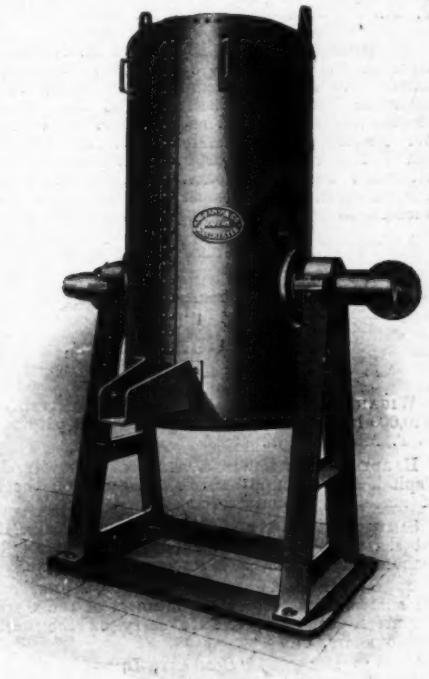
AS SUPPLIED TO THE ADMIRALTY, WAR OFFICE,
COLONIES, AND FOREIGN GOVERNMENTS.

THE Cupola.
Evans's Rapid.

Foundries Completely Furnished.

EVANS'S NEW CUPOLETTE
For Emergency Work.





James Evans & Co.,
Britannia Works,
Blackfriars,
MANCHESTER.

Telegrams: "LADLES, MANCHESTER."

ference on the subject of the education and training of engineers, at the Institution, on the 28th and 29th June. They are of opinion that the present is a desirable time to consider the methods of preparation to be adopted by those who contemplate entering the engineering profession, in compliance with conditions laid down by the by-laws for election into the Institution. It is intended to deal with this conference on broad lines; and it is desired to avoid restricting it to engineers only, much less to those who practice any particular branch of engineering. The idea of the Council underlying this conference is that whilst the general principle embodied in the Institution by-laws in regard to both education and practical training may be accepted as an expression of the general view of the large body of engineers who compose the Institution, there remain still unsettled a number of questions bearing upon the details of preparation to meet these conditions. Experience has shown that difficulties arise both in the stage of general and scientific education, and perhaps especially in that of practical engineering training, and it is thought these may be met or overcome in some degree by means of discussion of the several questions in detail, which seem to affect the root of these difficulties. The subject-matter of the conference will be dealt with in three groups, viz.:—(1) General education; (2) scientific training; (3) practical training. The following officers have been elected:—President of the Conference, Alexander Siemens, President Inst.C.E.; Vice-Presidents of the Conference, the Right Hon. Walter Runciman, President of the Board of Education, the Right Hon. Lord Pentland, Secretary for Scotland, Sir John Wolfe Barry, Past-President Inst.C.E.; Sir William H. White, Past-President Inst.C.E.; Honorary Secretary, James Forrest; General Secretary, J. H. T. Tudsbery; Section of General Education:—Chairman, Anthony G. Lyster, Vice-President Inst.C.E.; Vice-Chairmen, B. Hall Blyth, and H. A. Miers, Principal of the University of London; Honorary Secretaries, D. C Capper and E. P. Hill; Section of Scientific Training:—Chairman, W. C. Unwin, Vice-President Inst.C.E.; Vice-Chairmen, Sir Alexander B. W. Kennedy, Past-President Inst.C.E., and W. H. Maw; Honorary Secretaries, J. D. Cormack and Capt. H. Riall Sankey; Section of Practical Training:—Chairman, R. Elliott-Cooper, Vice-President Inst.C.E.; Vice-Chairmen, E. B. Ellington, James Swinburne, and W. B. Worthington, B.Sc.; Honorary Secretaries, J. W. Jacomb-Hood, E. W. Monkhouse, and Basil Mott.

New Companies.

WIGAN ENGINEERING COMPANY, LIMITED.—Capital £10,000 in £1 shares, to take over certain patents granted to T. Moss and W. Moss.

HARDEN, STAR, LEWIS & SINCLAIR COMPANY, LIMITED. Capital £5,000 in £1 shares, to carry on the business of machinery manufacturers, etc.

SAMUEL PEACE & SONS, LIMITED.—Capital £10,000 in £1 shares, to carry on the business of steel and file manufacturers, iron and steel merchants, etc.

GYRO MANUFACTURERS, LIMITED.—Capital £2,500 in £1 shares, to take over the business of the Gyro Manufacturers, Leicester, and to carry on the business of ironfounders, etc.

THOMAS HOLLIER & COMPANY, LIMITED.—Capital £500 in £1 shares, to take over the business of a brassfounder carried on at Newhall Street, Birmingham, as Thomas Hollier & Company.

RICHARD CRITTALL & COMPANY, LIMITED.—Capital £15,000 in £1 shares (10,000 preference), to carry on the business of engineers. Registered office: 197, Wardour Street, W.

DUNCAN STEWART & COMPANY, LIMITED.—Capital £50,000 in £1 shares, to carry on the business of general and manufacturing engineers and contractors, millwrights, boiler-makers, etc.

WELLINGS AND COMPANY, LIMITED.—Capital £1,000 in £1 shares, to take over the business of W. H. Wellings, Stanley Works, Wilson Street, Wolverhampton, and to carry on the business of engineers, etc.

ENGINEERING WORKS (ELECTRICAL AND GENERAL), LIMITED.—Capital £3,000 in 2,925 7½ per cent. preference shares of £1 and 1,500 deferred of 1s. Registered office: 7-8, Great Winchester Street, E.C.

CALEB A. V. ALLEN, LIMITED.—Capital £2,000 in £1 shares, to carry on the business of constructional engineers, founders, etc., as formerly carried on by C. A. V. Allen at High Street, Princes End, Tipton.

MOWAT'S PIONEER GRIT COMPANY, LIMITED.—Capital £2,000 in £1 shares, to acquire and carry on the business of D. Mowat & Sons, chilled iron sand manufacturers. Registered office: 11, Holland Street, Aberdeen.

GEORGE DENHAM & COMPANY, LIMITED.—Capital £5,000 in £1 shares, to act as fitters, iron and steel founders, engineers, pipe and tube makers, etc., and to acquire the business of George Denham & Sons, Limited.

BUCKMAN FOREIGN PATENTS SYNDICATE, LIMITED.—Capital £1,000 in £25 shares, to carry on the business of engineers, etc., and to adopt an agreement with R. S. Buckman. Registered office: 2, Clement's Inn, Strand, W.C.

GILLETT-STREET ENGINEERING COMPANY (PRESTON), LIMITED.—Capital £10,000 in £1 shares, to take over the business carried on by W. Worden, N. Miller and J. Clarke, at Preston, as the Gillett Street Engineering Company.

PRECISION TOOL COMPANY, LIMITED.—Capital £1,000 in £1 shares, to acquire the business of the Precision Tool Company (late Wood & Knight), Bristol Street, Birmingham. Registered office: 40½, Bristol Street, Birmingham.

ARCHIBALD LOW & SONS, LIMITED.—Capital £25,000 in £1 shares, to acquire the businesses of Archibald Low and the Partick Brass Foundry Company, Merkland Works, Partick, Glasgow. Registered office: 78, Merkland Street, Partick, Glasgow.

INTERNATIONAL STEEL COMPANY, LIMITED.—Capital £25,000 in £1 shares, to acquire any invention relating to the manufacture or production of metals, alloys, or similar substances, etc., and to adopt an agreement with the Hansen Tarlton Syndicate.

C. W. WALLACE, BRUCE & COMPANY, LIMITED.—Capital £10,000 in £1 shares, to acquire the engineering business formerly carried on by C. W. W. Bruce, at Barrack Road, Newcastle-on-Tyne. Registered office: 12, Barrack Road, Newcastle-on-Tyne.

VICTORIA BRASS FOUNDRY COMPANY, LIMITED.—Capital £8,000 in £1 shares, to acquire and carry on the business of Ebenezer Chalmers, Bonnington, Leith, carried on under the name of James Buchanan & Company. Registered office: 236, Leith Walk, Leith.

WM. CAMPBELL & COMPANY, LIMITED.—Capital £6,000 in £1 shares (3,500 preferred), to acquire and carry on the business of brassfounders, general metal merchants, etc., carried on at Belfast, under the style of Wm. Campbell & Company. Registered office: 6, Talbot Street, Belfast.

STEEL AND GARLAND (1911), LIMITED. — Capital £10,000 in £1 shares, to acquire the business carried on at Worksop, Notts, and elsewhere, by Steel and Garland (1905), Limited, and to carry on the business of manufacturers of and dealers in stove grates, hot air stoves, etc.

R. G. HOLLAND & COMPANY, LIMITED.—Capital £12,000 in £1 shares, to carry on the business of manufacturers and sellers of and dealers in steel, iron, and other metals, etc., and to acquire the business carried on by the late R. G. Holland, of Sheffield. Registered office: Clarence Works, Burton Road, Sheffield.

R. H. PATTERSON & COMPANY, LIMITED. — Capital £10,000 in £1 shares (3,000 6 per cent. cumulative preference) to take over the business of an engineer, iron and machinery merchant, valuer and assessor, carried on by R. H. Patterson, at Forth Street Works, Newcastle-on-Tyne, as R. H. Patterson & Company.

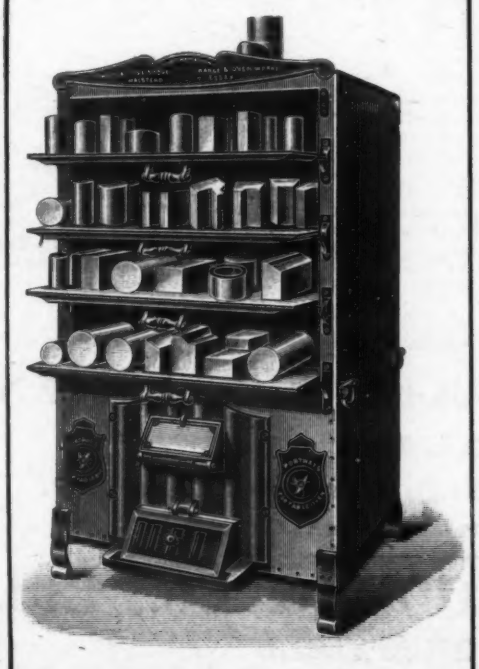
KEITH-BLACKMAN

HIGH PRESSURE BLOWERS.

For AIR BLAST to SMITH'S HEARTHS, CUPOLAS, FURNACES, BRAZING TOOLS, &c.

BELT-DRIVEN, or directly combined CONTINUOUS or ALTERNATING CURRENT MOTORS.

JAMES KEITH & BLACKMAN CO., LD.
27, FARRINGDON AVENUE, LONDON.



THE

"PORTWAY" CORE OVENS

The Newest and Best in the World.

MADE TO CONSUME GAS COKE, REFUSE CINDERS, GAS, etc., etc.

These Ovens are also suitable :: :: for Japanning Work. :: ::

SEND FOR LIST TO

CHAS. PORTWAY & SON,
HALSTEAD, ESSEX.

Inventions.

Applications for Patents.

An asterisk indicates that a complete specification accompanies the application. When inventions are communicated the names of the communicators are in brackets.

8,362. Annealing or heat treatment of metals and alloys and apparatus therefor. T. V. Hughes.
8,498. Manufacture of steel. T. D. Mackie and G. F. Forwood.
8,514. Muffle furnaces. A. C. Ionides, jun.
8,671. Furnace for the melting of all metals requiring the use of the crucible. J. E. Bayley.
8,817.*Sand moulding machines. Soc. Anon. des Etablissements Ph. Bonvillain and E. Ronceray.
8,818.*Moulding machines. Soc. Anon. des Etablissements Ph. Bonvillain and E. Ronceray.
8,897. Manufacture of chrome steel. G. Feodosieff.
8,901.*Electric furnace. E. Stassano.
8,998.*Electric furnaces. (J. E. Florence, United States.)
9,031. Smelting or refining of metals in crucibles. H. G. Solomon.
9,070. Electric furnaces. C. Fischer.
9,227. Aluminium alloys. B. J. Smart.
9,592. Process of annealing crucibles used for steel melting. E. Boothby.
9,633.*Electrodes for electric furnaces. (Shawinigan Carbide Company, Limited, Canada.)
9,652.*Carbon electrode for electric furnaces. (Planiawerke Akt.-Ges. fur Kohlenfabrikation Ratibor, Germany.)
9,754. Method and means for driving metal out of holes in faulty furnace bottoms. R. Leyshon.
9,771. Substitute for moulding sand. D. M. Mac-Pherson.
9,862. Mounting patterns for moulding. H. Rix and W. Moore.
9,955. Sand mould jarring machine with pattern-plate fixing arrangement, mechanically driven or worked by hand. J. J. Chipchase.
10,084. Apparatus for moulding. W. Moore and H. Rix.
10,127.*Grinding machines. (Lewis Fisher Fales, United States.)
10,401. Manufacture of metal taps and vents. H. C. B. Lamb and H. G. Barraud.
10,789. Machinery for filling and translating mould boxes. P. Taylor.
10,858.*Electric furnaces. H. Plauson, W. Zsvetaeff, and G. Tistchenko.
10,900. Method of manufacture of ferro-alloys for steel making. F. Hodson.
10,939.*Furnaces for smelting metals. F. W. Winner.
11,685. Appliances for drying moulds. A. B. Roxburgh and J. Dobeson.
11,838.*Apparatus for shaking ingot moulds. Mensing, Bruckmann et Cie.
11,846.*Manufacturing a refractory and abrasive product. I. Werlein.

Personal.

Sir Joseph Jonas, of Jonas & Colver, Limited, Sheffield, has been elected president of the Sheffield Reform Club.

The late Mr. G. D. Connell, of Fairhill, Hamilton, N.B., a Glasgow ironbroker, left personal estate valued at £7,513.

The late Mr. R. Smith, iron merchant, Broomgrove Road, Sheffield, left estate of the gross value of £103,996, with net personalty £98,946.

The gross value of the estate of the late Mr. J. Trippett, of Messrs. Joseph Trippett & Sons, Standard Steel Casting Works, Sheffield, is £6,947.

Mr. A. McCormack, technical manager to the Wolseley Tool and Motor-Car Company, Limited, has been elected managing-director of the company.

The late Mr. J. Spencer, of John Spencer, Limited, of the Globe Tube and Engineering Works, Wednesbury, left estate valued at £38,920 gross, with net personalty £35,802.

The announcement is made this week that Mr. G. Foster Martin, J.P., has resigned his position as general manager of the Blaenavon Company, a position he has held for the last eight years.

Mr. Alfred Stephens, J.P., principal of the firm of Messrs. Stephens & Company, silica brick makers, Kidwelly, has been selected as the prospective Tariff Reform candidate for West Carmarthenshire.

Mr. H. Marshall, assistant yard manager to Palmer's Shipbuilding and Iron Company, Limited, Jarrow, has received an appointment as manager over the Government work at Messrs. Cammell, Laird & Company's yard at Birkenhead.

Mr. John Reis, who has been assistant to the president in charge of construction work, has been elected vice-president of the United States Steel Corporation, in place of Mr. Wm. B. Dickson, resigned. The appointment of Mr. W. B. Perley as assistant to the president, is also announced. Mr. Perley was previously assistant to Mr. Dickson.

Owing to failing health, Mr. J. F. Swallow has resigned his seat on the board of the Parkgate Iron and Steel Company, Limited. He has been a director since 1898, and has always taken a great interest in the welfare of the company. The vacancy thus caused has been filled by the election of Mr. Henry Westlake, managing director of the Staveley Coal and Iron Company, Limited.

Mr. T. L. Lintern, consulting engineer, of Cardiff, has been appointed chief engineer to the Hughesovka Iron and Steel Company, South Russia. Mr. Lintern (who was trained at the Dowlais Works) has held the position of chief engineer to the Weardale Steel, Coal and Coke Company, Limited, and has acted as chief engineer to the Cargo Fleet Iron Company, Limited, Middlesbrough.

GANISTER, CUPOLA BLOCKS, FIRE BRICKS,
FIRE CLAY.
Silica Bricks, Tuyeres, Stoppers, Nozzles, &c.
STEEL MOULDERS' COMPOSITION, SILICA CEMENT.
J. GRAYSON LOWOOD & Co., Ltd.,
DEEPCAR, nr. SHEFFIELD.
Telegrams: "LOWOOD, DEEPCAR."

SOUND

STRONG, CLOSE-GRAINED

CASTINGS

Obtained by using

"TITANIUM THERMIT"

TINS READY FOR USE. ALL SIZES from 2 cwt. to 20 tons.

Prices and Particulars from

THERMIT LIMITED,

Telegrams: "FULMEN, LONDON."
Telephone: 3749 Central.

27, Martins Lane,
Cannon Street, E.C.

Works: 210a, Bow Rd., E.

ELDERS FOUNDRY COKE

AS SUPPLIED TO THE
BRITISH
ADMIRALTY DOCKYARDS.

The following, selected from numerous letters, are eminent testimony as to the quality of our celebrated "A.A.A." Coppee Foundry Coke, carefully selected, and despatched in sheeted wagons.

From PECKETT & SONS, Bristol.

Bristol, October 25th, 1904.

We have been using your Selected Foundry Coke for some considerable time.
We have pleasure in stating that we are very pleased with it, as we find we get sounder and cleaner castings, more free from blowholes and other defects, than we formerly did.

From BOW, McLACHLAN & CO., LTD. (Paisley Foundry), Paisley, Glasgow.

Paisley, 12th March, 1909

We have yours of 4th inst., and in reply have pleasure in stating that we have been using your Foundry Coke for several years for special purposes with highly satisfactory results.

Elders Collieries, Ltd., Cardiff.

Deaths.

MR. C. HOLMES, of Messrs. Holmes & Pearson, Royal Ironworks, Keighley, died recently.

MR. W. TIMMINS, J.P., of E. Timmins & Sons, Limited, Bridgwater Foundry, Runcorn, Cheshire, died recently.

MR. J. HORRICKS, of Gresham & Craven, Limited, Craven Ironworks, Salford, Manchester, died recently at the age of 81 years.

MR. G. E. EVANS, who at one time owned the Emlyn Engineering Works and Foundry, Newport (Mon.), died recently, aged 85 years.

MR. W. LEES, of Walter Lees & Company, Limited, iron and brassfounders, Bedford Street, Halifax, died recently at the age of 64 years.

THE death occurred at his residence, Butterley Carr, Ripley, recently, of Mr. William Joseph Morris, works manager for the Butterley Company, Ltd., at their Butterley Ironworks. He was 40 years of age, and went from Sheepbridge to Butterley just over four years ago.

MR. WILLIAM CASTLE, C.B., R.N., died on May 8, at his residence, at Friern Park, North Finchley, N. The deceased gentleman entered the Royal Navy as assistant engineer in 1855, became chief engineer 1872, inspector of machinery 1885, chief inspector 1889, and retired in 1893.

THE death took place at his residence, 6, Broomfield Road, Sheffield, on May 14, of Mr. F. Schwab, head of the firm of J. Shipman and Co., Limited, steel and wire manufacturers, Attercliffe Road, Sheffield. The deceased gentleman, who was 65 years of age, had been an invalid for several years.

MR. H. B. Jones, a steel and file manufacturer of Sheffield, died at his residence, Collegiate Crescent, Sheffield, on May 9, at the age of 55 years. He was the eldest son of the late Mr. George Rose Jones, who founded the firm of G. R. Jones & Company, Swedish Steel and File Works, Sheffield, of which the deceased was at the time of his death, the senior partner.

PRICES OF METALS.

The following table shows the approximate latest prices and position of stocks of metals during the past wo years :—

METALS.	End May 1911.	End May 1910.
Iron—Scotch pig warrants ton	*52/9	*55/10½
—Middlesbro' warrants ... ton	46/10½	49/11
—W.C. M/nos Bessemer ... ton	65 0	68 0
—Stock, Scotch ... ...tons	1,060	1,000
Copper—Chili bars, GMB ton	£55 2 6	£56 7 6
—Stock, Europe and afloat tons	—	—
Tin—English ingots ... ton	£197 10 0	£149 0 0
—Straits ... ... ton	£193 15 0	£150 5 0
—Stock, London, Holland, U.S.A., and afloat ...tons	—	—
Lead—English pig ... ton	£13 7 6	£13 0 0
Spelter—Ord. Silesian ... ton	£21 8 9	£22 1 3
Quicksilver (75lb)... bottle	£8 5 0	£8 15 0
Antimony—Regulus ... ton	£29 10 0	£30 0 0 £30 10 0

* Settlement price.

CASTINGS.

In the Cleveland district the following are the nominal rates current for castings :—

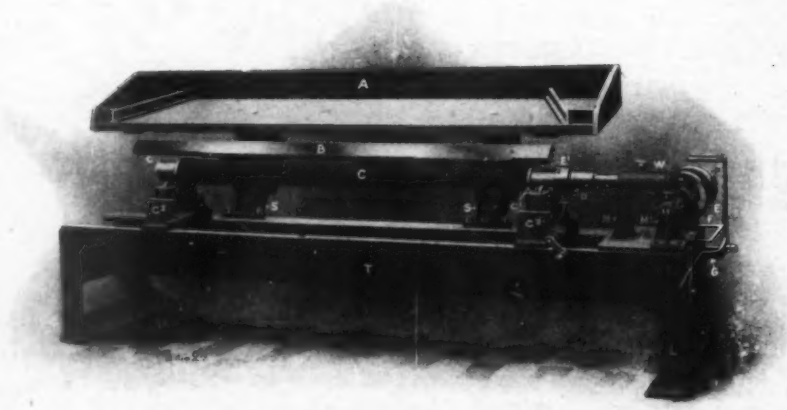
	£ s. d.		£ s. d.
Columns (plain)	6 10 0	to	6 15 0
Pipes, 1½ to 2½ in.	4 17 6	to	5 2 6
,, 3 to 4 in.	4 10 0	to	5 0 0
,, 5 to 8 in.	4 7 6	to	4 10 0
,, 10 to 16 in.	4 7 6	to	4 10 0
,, 18 to 24 in.	4 7 6	to	4 10 0
Chairs	3 12 6	to	3 15 0
Floor plates (open sand)	3 0 0	to	3 5 0

SCRAP.

The quotations for scrap, subject to market fluctuations, are as follows :—Heavy wrought (mixed), £2 10s. 0d.; light wrought, £1 7s. 6d.; heavy cast-£2 7s. 6d.; all per ton, f.o.b., London. Copper (clean), £51 10s. 0d.; brass (clean), £38 10s. 0d.; lead (usual draft), £12 0s. 0d.; zinc, £19 15s. 0d.; all per ton delivered merchant's yard.

Core-Forming Machine

(W. JONES' PATENT).



For making sand-pipe cores from 10 inches to 10 feet, and any diameter from 1 inch to 20 inches.

Cores made in half the time and at half the cost of the old system.

Jones & Attwood, Ltd., Engineers, Stourbridge.

Established 1863.

JAS. DURRANS & SONS,

PHŒNIX WORKS, PENISTONE, Near Sheffield.

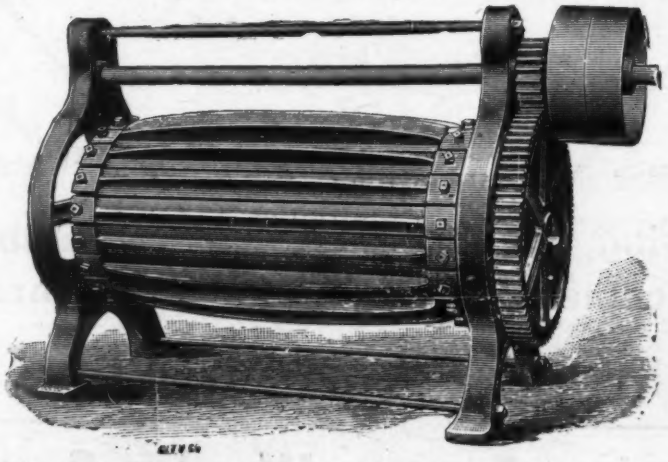
Manufacturers of all

FOUNDRY EQUIPMENTS,

COMPOSITION BLACK LEAD, PLUMBAGO, CORE GUM, WHITE DUST & COAL DUST.

Ladles, Cupolas, Fire Bricks, Gannister, Stone Flux, Loam and Sand Mills, Casting Cleaners, Studs, Chaplets, Pipe Nails, Sprigs, Brushes, Wire Brushes, Core Ropes, Bellows, Buckets, Spades, Forks, Riddles, Sieves, Barrows, Etc.

IMPROVED FOUNDRY RATTLER or FETTLING DRUM.



These Machines are invaluable for a Foundry, doing a larger amount of work of a superior quality, in a much shorter time than can be done by hand, without skilled labour.

"Dear Sirs,—We have been using your best Blacking for a large number of years, and always use it on our large Ingot Moulds, which, as you know, we have made up to 85 tons in weight.

Yours faithfully, THE BRIGHTSIDE FOUNDRY & ENGINEERING CO., LD."

Foundries Completely Equipped.

Cupola Hoists.

Cupolas.

Ladles.

Sand Mills.

Sifting and Mixing Machines.

FOR ALUMINIUM, BRASS, MALLEABLE, or STEEL.

MODERN FOUNDRY EQUIPMENT

ALL OUR Machines are designed and constructed for heavy duty, and will withstand for years the severest usage.

Write for . . . Catalogues.

Core Ovens.

Core Making Machines.

Moulding Machines.

Pig Breakers.

Tumbling Barrels.

Sand Blast Plants.

The London Emery Works Co., PARK WORKS,

TOTTENHAM, LONDON, N.

THE BUYER'S GUIDE

Addresses and further information will be found by reference to the Firm's Advertisement.

Abrasive Wheels.
Evans, J. & Co.
London Emery Works Co.
Jackman, J. W., & Co. Ltd.

Air Compressors.
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Phillips, J. W. & C. J.
Thwaites Bros., Ltd.
Tilghman's Patent Sand Blast Co., Ltd.

Air Compressors (Electrically Driven).
Jackman, J. W., & Co., Ltd.
Marshall & Co. Horace P.
Tilghman's Patent Sand Blast Co., Ltd.

Air Compressors (Steam).
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Tilghman's Patent Sand Blast Co., Ltd.

Air Compressors (Belt).
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Tilghman's Patent Sand Blast Co., Ltd.

Annealing.
Evans, J. & Co.
Phillips, J. W. & C. J.

Ash Crushing and Washing Machines.
Evans, J., & Co.
Jackman, J. W., & Co., Ltd.
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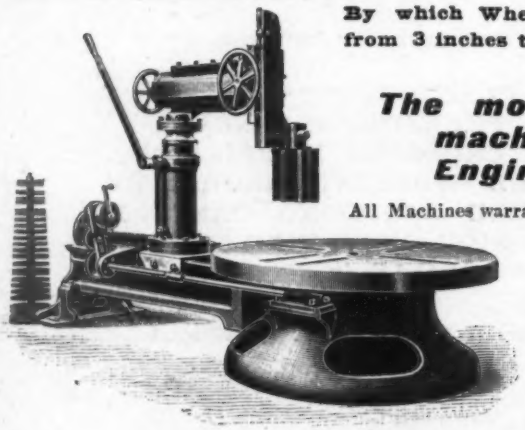

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	Jenkins, W. J. & Co., Ltd.	Retford	Jenkins, Retford	—
422	Jones & Attwood, Ltd.	Stourbridge	Heat, Stourbridge	10, Stourbridge
373	Keith, James, & Blackman, Co., Ltd.	27, Farringdon Avenue, London	James Keith, London	6194 H'lb'rn(4 lines
372	King, Bros. (Stourbridge), Ltd.	Stourbridge	King Bros., Stourbridge	—
424	London Emery Works Co., Ltd.	Park, Tottenham	Naxium, London	99 Tottenham
420	Lowood, J. Grayson, & Co., Ltd.	Deepcar, nr. Sheffield	Lowood, nr. Sheffield	18 Stocksbridge
371	Macdonald, J. & Son, Ltd.	Maryhill, Glasgow	Compressor, Glasgow	161 Mary Hill
374	Marshall, H. P., & Co.	Leeds	Specialty, Leeds	909 Leeds
369	Metalline Cement Co.	112, Bath Street, Glasgow	Adh-sive, Glasgow	01Y2 Douglas
369	Mitchell's Emery Wheel Co.	Bradford, Manchester	Diameter, Manchester	2Central, 3575
368	McNeil, Chas.	Kinning Park, Glasgow	McNeil, Glasgow	X 155
420	National Time Recorder Co.	—	—	—
366	Olsen, William	Cogan Street, Hull	Wm. Olsen, Hull	599 Y.I.
366	Phillips Chas. D.	Newport, Monmouthshire	Machinery, Newport	18 P.O. 576
366	Phillips J. W. & C. J.	23, College Hill, E.C.	Colloquial, London	10112 Central.
C. iii.	Plasti-Kion Co., Ltd.	Caxton House, S.W.	—	—
374	Portway, C. & Son	Halstead, Essex	Portway, Halstead, Essex	10 P.O. Halstead
C. iii.	Robeson Process Co.	—	—	—
372	Silent Machine Co.	Albion Works, Salile St., Sheffield.	Forward, Sheffield	—
	Samuelson & Co., Ltd.	Banbury	Samuelson, Banbury	—
365	Standard Sand Co., Ltd.	Mansfield	Standard Sand Co., Mansfield	201 Mansfield
371	Stewart, D., & Co. (1902) Ltd.	London Road Ironworks, Glasgow	Stewart, Glasgow	271 P.O. Bridgt'n 3243 Bridgton(N
366	Sykes, James	Ashton-under-Lyne.	—	—
421	Thermit, Ltd.	27, Martin's Lane, E.C.	Fulmen, London	3749 Central
423	Tilghman's Patent Sand Blast Co., Ltd.	Broadheath, nr. Manchester	Tilghmans, Altrincham	14
375	Thwaites Bros., Ltd.	Bradford	Thwaites, Bradford	325 Bradford
	Vaughan & Sons, Ltd.	West Gorton, Manchester	Vaunting, Manchester	5113 Central
372	Walker, I. & I.	Rotherham	—	—
428	Whittaker, W., & Sons, Ltd.	Oldham	Whittakers, Engineers, Oldham	83 —
369	Wilkinson, Thos., & Co., Ltd.	Middlesbrough	Blacking, Middlesbro.	419
302	Williams, J (B'ham Sand) Ltd.	Birmingham	—	—

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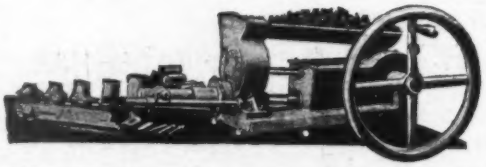

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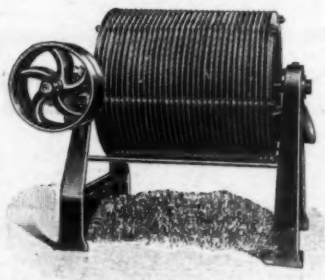

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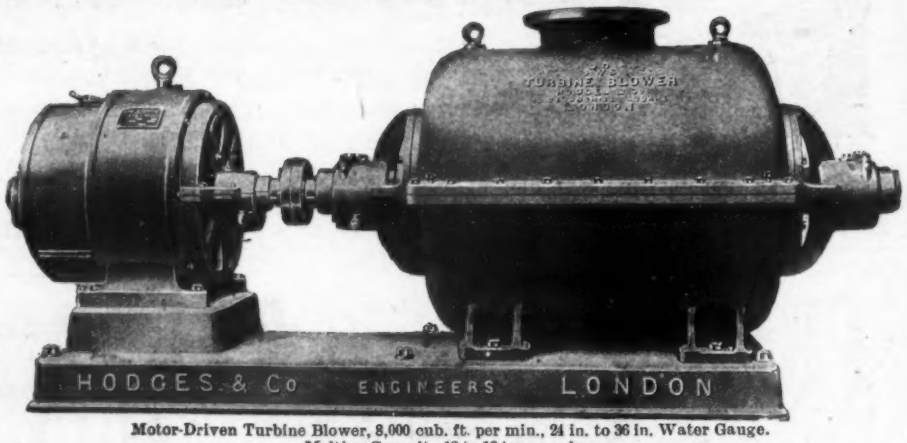

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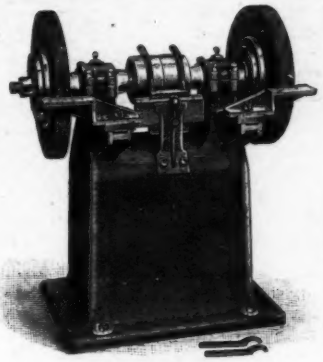

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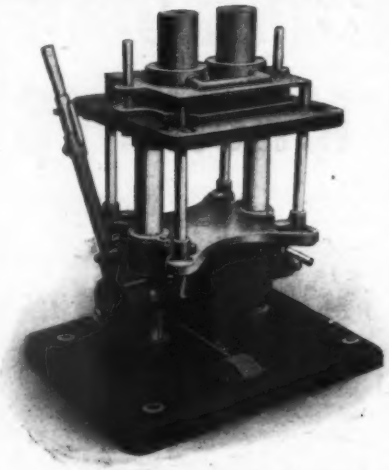

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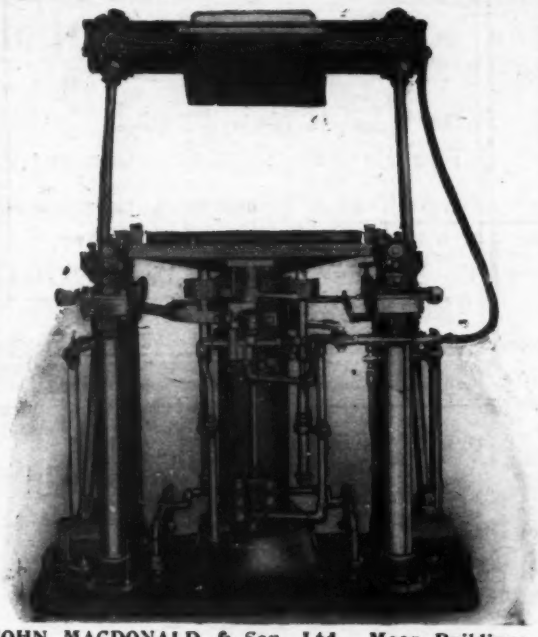

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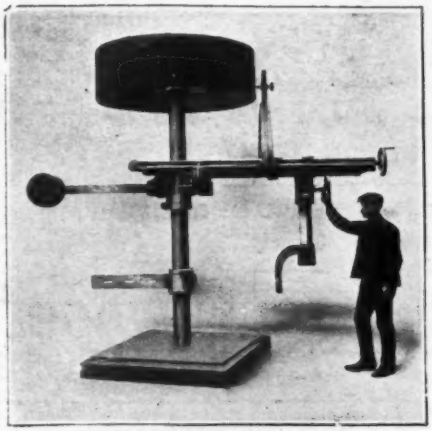

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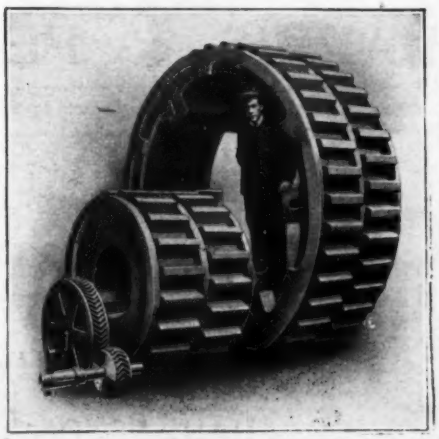

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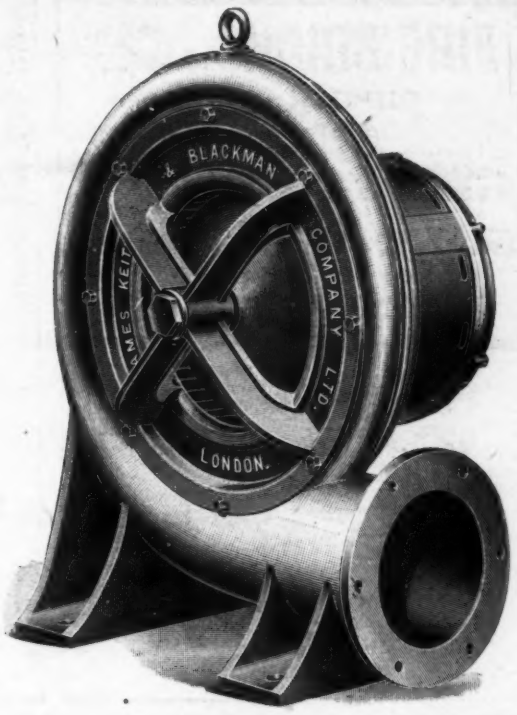

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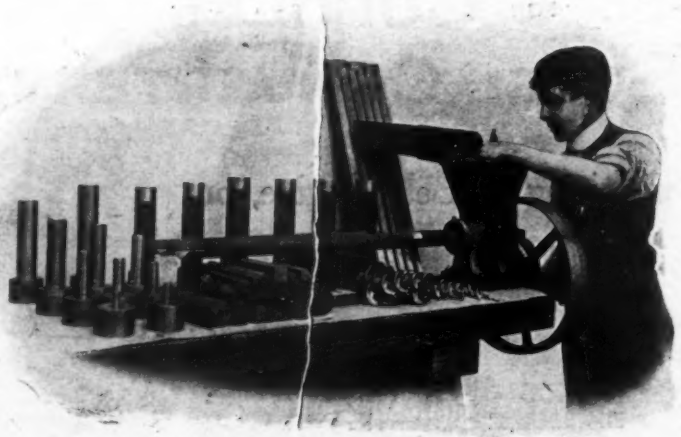

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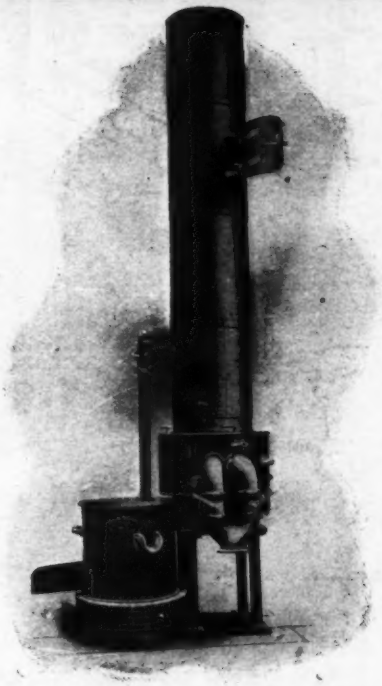

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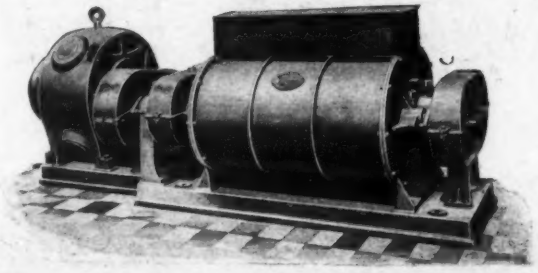

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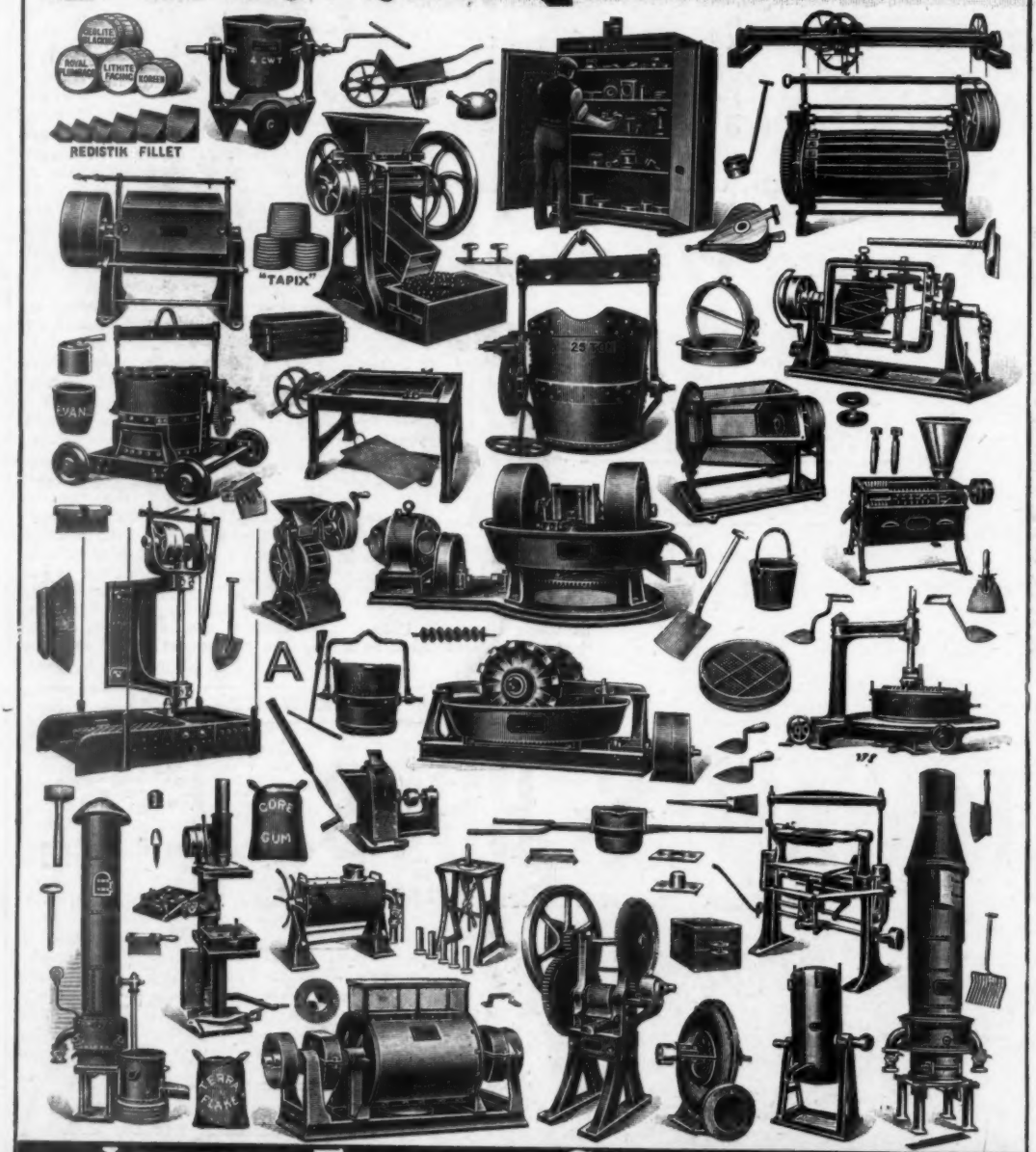

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